Analysing operational cost performance in selected gold mines in South Africa

S Taylor

orcid.org/0000-0002-0628-4628

Mini-dissertation accepted in partial fulfilment of the requirements for the degree *Masters of Business Administration* at the North-West University

Supervisor: Dr JA Jordaan

Graduation: May 2022
Student number: 26316919

ABSTRACT

Gold mines are essential for the economic well-being of South Africa. It is a job creator and contributes billions of Rands in taxes. South Africa has always been the leader in gold production, but performance has lacked in the past fifteen years.

The studies goal was to determine the benefits of using Earned Value Management (EVM) as a tool to track progress and cost on operation cost and to demonstrate its potential benefits.

This study was conducted on ongoing-capital-development and stoping parameters with data over the past three years.

Further to the physical tracking of the progress, this study demonstrates how effectively EVM can forecast both the Estimated Cost at Completion (EAC) and Schedule at Completion (SAC) when financial budgets and production targets are planned over a longer duration. The EVM methodology gives the manager an understanding of where the progress may end if the current performance regarding cost and production is maintained.

During my involvement in capital projects over the past 25 years, I could never understand the need for managing operational costs and capital costs differently. The operating cost planning is done in much more detail but only executed over a year. This funding is called "working cost" and is approved annually.

Capital planning is in minor detail, but the budget is approved for longer durations. The project team must complete all deliverables within the extended time frame with approved funding over an extended period. When comparing these two costs, the working cost on a production mine is much higher than the capital, and should these costs be ill-managed, it is likely to have more significant consequences.

This study demonstrates the benefit of Earned Value Management (EVM) on operational cost. If any deviations are noted early, the potential impact that may be caused is reflected in the cost and production management.

No previous research on this management methodology on working costs was found.

This study is quantitative and is fact-based, calculated with actual data from a mine. The findings demonstrate that millions of Rands can be saved by implementing EVM.

KEY TERMS

Key terms used in this research with description:

i. Earned value management

"Earned value management (EVM) is a powerful methodology that gives executives, project managers, and other stakeholders the ability to visualise project status throughout the project life cycle and consequently manage projects, programs, and portfolios more effectively" (Anbari, 2011).

ii. Ongoing-capital-development (OCD)

Process of accessing an orebody through tunnelling in underground mining operations. These tunnels are on average 3 m wide and 3 m high and can be km's in length.

iii. Stoping (Encyclopaedia, 2021)

It is extracting ore via underground processes.

iv. Capital projects

Capital is funded by investors and is used for the expansion (increase production volumes), replacement (sustaining production volumes), and Stay-in-business (safety and production integrity assurance) processes.

v. Operating cost

Supply financing for the operational expense to produce gold.

ACKNOWLEDGEMENTS

I am grateful to my Creator and all for giving me the mental and physical ability to do a Mini-dissertation and an MBA at my age. Thank you for giving me the opportunity and guidance during such a privileged period of my life.

A special thanks to all members of management at the mine for making their time and resources available to me. Thank you to the group COO, the Senior Accountant, and the Senior Mine-Planner for granting me permission to use their data.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF GRAPHS

ABBREVIATIONS

List of abbreviations as per the table below:

Table 1: List of abbreviations

Abbreviation	Meaning
AC	Actual cost
ACWP	Actual cost work performed
BCWP	Budgeted work performed
BCWS	Budgeted work scheduled
CAD	Computer-aided design
Cap	Capital
Capex	Capital expenditure
CPR	Cost performance ratio
CV	Cost variance
EAC	Estimate at completion
EV	Earned value
EVM	Earned value management
IRR	Internal rate of return
ITC	Indicated total cost
kg	Kilograms
km	Kilometres
LOM	Life of mine
lvl	level
LOM	Life of Mine
m^2	Square meters (centares)
m^3	Cubic meters
mcf	Mine call factor
m	metres
Moz's	Million ounces
NPV	Net present value
Opex	Operation expenditure
OCD	Ongoing-capital-development
ORM	Ore reserve management
Oz.	ounces

Abbreviation	Meaning
PMBOK	Project Management body of knowledge
PV	Planned value
R	South African Rands
SPR	Schedule performance ratio
SV	Schedule variance
SWP	Summary work packages
t	ton
WBS	Work breakdown structure
$	United States of American Dollars

1 CHAPTER 1 – CONCEPTUALISATION OF THE RESEARCH

1.1 INTRODUCTION

The research objective is to determine if Earned Value Management (EVM) can play a proactive role in managing operational costs regarding cost savings and increased production in the gold mining industry.

With 25 years of experience in project management in the mining sector, I have the required knowledge to research this topic. The results of this study will positively contribute to the gold mining sector and will prolong job security, and ensure stakeholder benefits.

The research can be adopted for any mine as the cost and production methodologies remain the same.

The mine that supplied the research data (cost budgets, production targets, and actual achievements) will remain anonymous as it may harm the shareholders' perception of this sensitive data. The mine will be called "A-Mine" for the purpose of this study.

This chapter provides the background of the SA gold mining industry as well as the problem statement.

1.2 BACKGROUND AND HISTORY OF SA GOLD MINES

Gold was first discovered in South Africa on the banks of the Witwatersrand by Jan Gerrit Bantjes in June, 1884 (History, 2016).

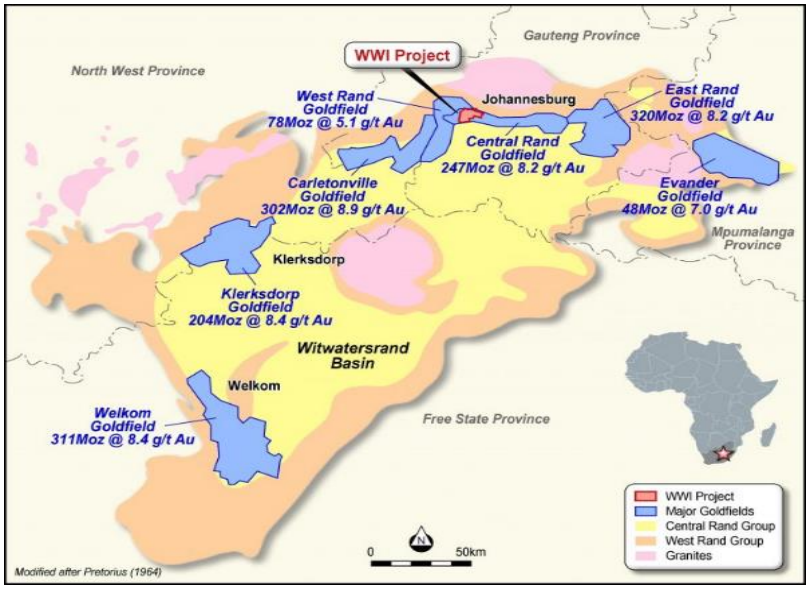


Figure 1: Witwatersrand basin area (Blue) **(Mining, 2021)**

Jan’s father, Jan Gerritze Bantjes, was the Secretary General of the Voortrekkers and was the author of the treaty (06 February 1838) between the Zulu king (Dingane) and the Voortrekkers’ leader (Andries Pretorius) (Guide, 2021). South Africans currency derives from the name "Witwatersrand," an Afrikaans word (OANDA, 2020). The term “rand” directly translates to English as "ridge" or "reef".

Figure 2: South African 1 Rand coin **(Club, 2021)**

The Witwatersrand basin covers a significant area of South Africa, and the central location is demonstrated in Figure 1, highlighted in blue. More than 1.5 billion ounces of gold (40,000 tonnes) (Mining, 2021) was produced in this area. The basin’ area is close to 350 km from the North-East to the South-West direction in length. This reef is solely responsible for approximately 30% of all the gold ever produced in the world to date (Harper, 2020).

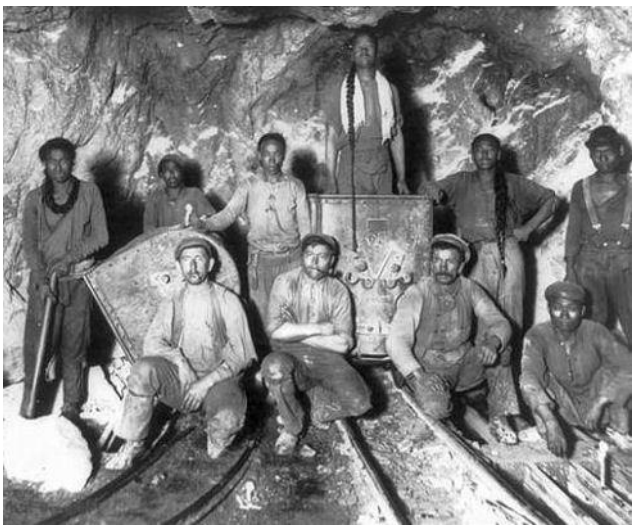


Figure 3: Gold miners during the gold rush **(Artifacts, 2021)**

There are currently 86 gold mines operational in South Africa (IQ, 2019), of which most are underground operations.

Access to ore bodies is mainly through open-pit mining, decline shafts or ramps, vertical shafts, or a combination of all.

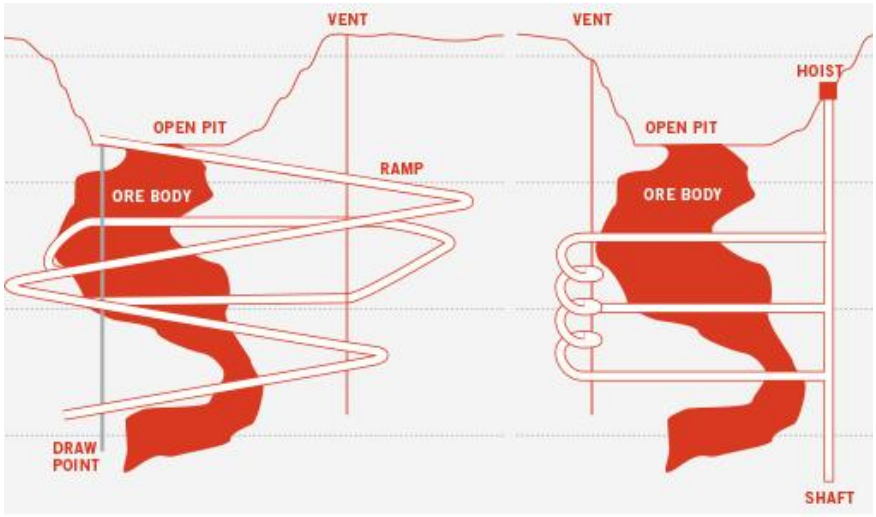


Figure 4: Mining access options **(Viewpoint, 2021)**

Currently, Mponeng mine, owned by Harmony Gold, is officially the deepest mine in the world. The mine's operations extend past 4 km (Gold(B), 2021) below the surface.

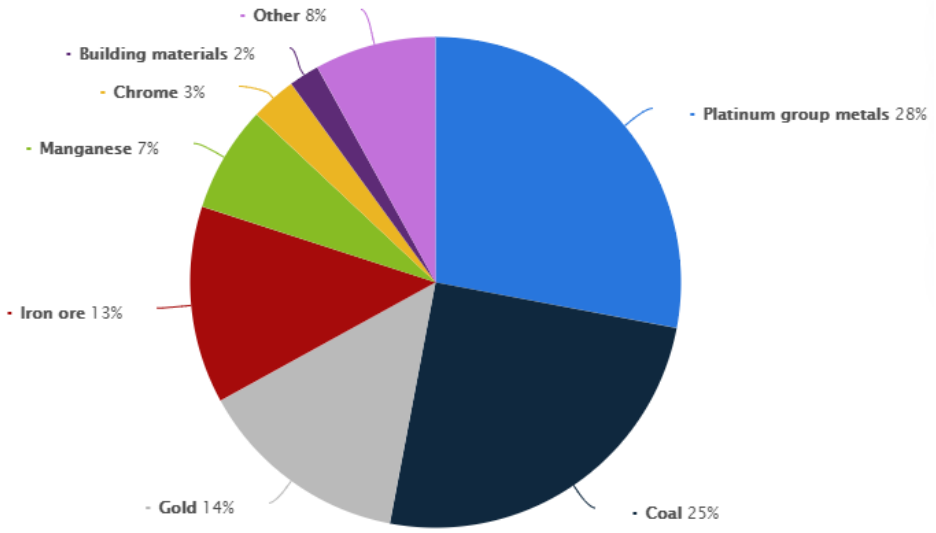
The three primary gold-producing companies in South Africa are Goldfields, Harmony Gold, and Sibanye Stillwater. The remaining total resources available at their most significant operations are:

a) Goldfields (Goldfields-Southdeep, 2021).
   - South Deep - 912,855 kg (32.2 million Oz)

b) Harmony Gold (Gold(A), 2021).
   - Tshepong operations - 796,000 kg
   - Target 1# - 113,000 kg
   - Doornkop - 227,000 kg
   - Kusasalethu - 184,000 kg
   - Mponeng - 733,000 kg
   - MOAB Khotsong - 386,000 kg

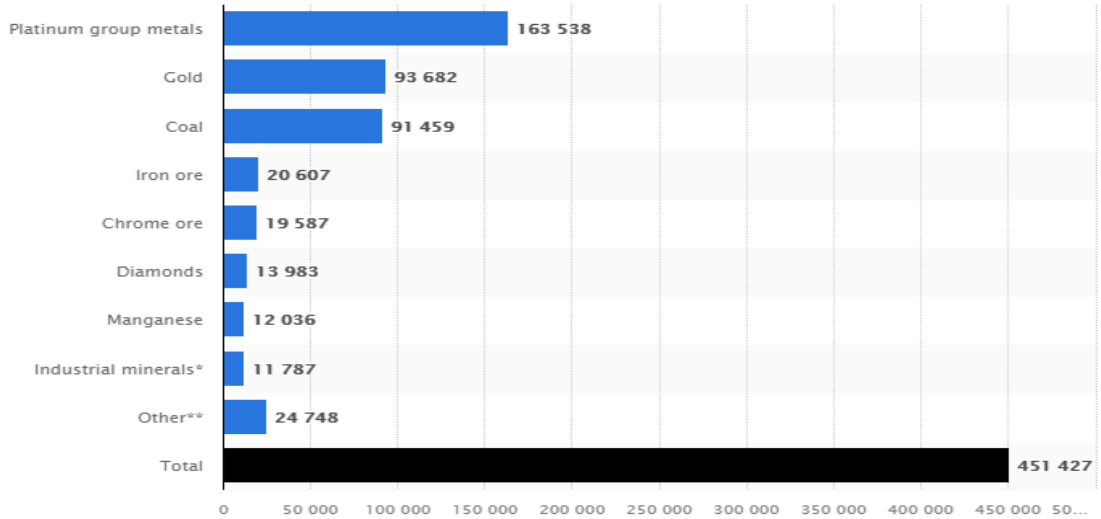
c) Sibanye Stillwater (Stillwater, 2021).
   - Kloof (all operations) - 932,699 kg (32.9 million Oz)
   - Beatrix (all operations) - 311,845 kg (11.0 million Oz)
   - Driefontein (all operations) - 320,350 kg (11.3 million Oz)

The mining sector, including all commodities, contributed R 400 billion to the GDP of South Africa during 2020 (Accram, 2021). This contribution was 8.2 % of South Africa's total GDP for 2020. The mining industry has, in the past, contributed 21% of South Africa's GDP during the 1980s (Buthelezi, 2021). Does this mean the gold resources have depleted, or did South Africa's proud mining heritage die?



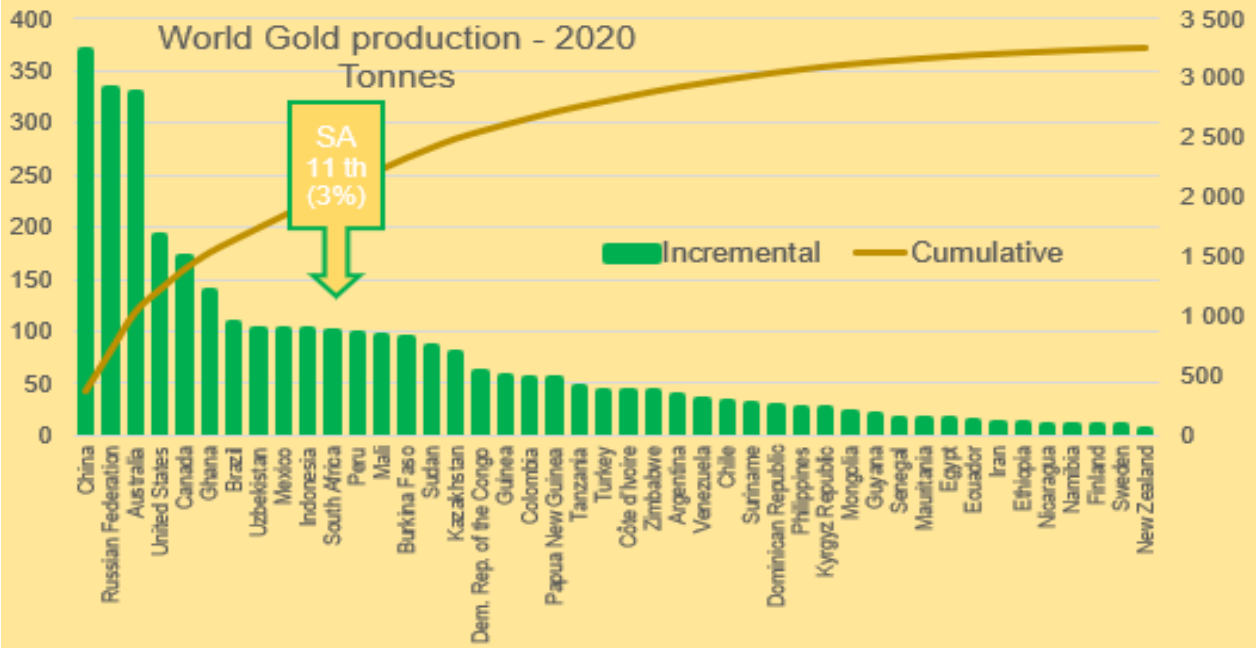
Graph 1: Revenue per mining sector 2020 **(Garside, 2020)**

The gold mining sector contributed 14% of the total revenue realised by the mining sector, as seen in Graph 1. The mining sector has also secured employment for 451,427 people (Garside, 2021). Gold mining has employed 20.7% of the total mining employees during 2020, and finding a method in increasing sustainability is becoming more critical.



Graph 2: Employees per mining sector **(Garside, 2021)**

South Africa was the leading gold producer in the world until 2006 (Wikipedia, 2021). As seen in Graph 3, other countries have steadily explored opportunities and increased their production to become world-leading producers, leaving South Africa behind.

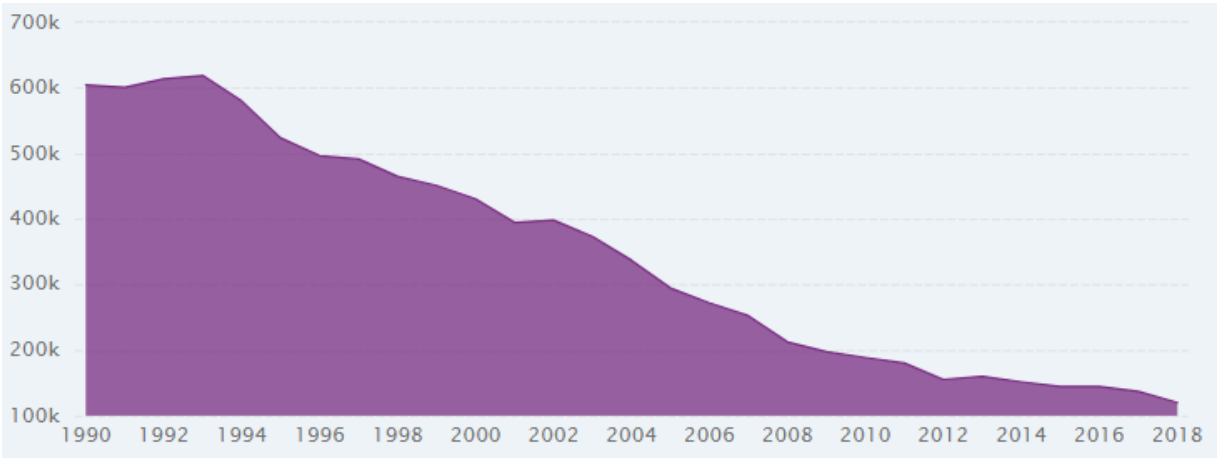


Graph 3: World Gold production - 2020 **(GoldHub, 2021)**

Areas that influence the mining profitability and success in South Africa are mostly (LaneI, 2015) related to:

- Rand / $ exchange rate;
- political interference;
- commodity prices and rising production costs;
- increased labour and energy costs;
- constant demands from employees and unions; and
- government expectation that mines should fulfil social needs.

The importance of South Africa's mining sector is evident. Any solutions that may enhance the mining operation must be studied. These solutions are not limited to the actual mining below the surface but can also be more innovative in management.



Graph 4: South Africa declining gold production **(CEIC, 2021)**

South Africa's highest recorded annual gold production was 619.2 tonnes during 1993. The lowest ever gold production for South Africa was during 2020, with only 90 tonnes (CEIC, 2021). Although Covid-19 most certainly played a role in this poor production year, 2019 (without any pandemic) also recorded a low production achievement of 105 tonnes.

Gold has always been a good investment during stages of political and economic uncertainty. Gold consumption in the world is as follow (Economics, 2021):

- Jewellery - 50%.
- Investments - 40%.
- Industries - 10%

Graph 5: Gold price history $ per Ounce **(Economics, 2021)**

There is no question that gold mining remains an excellent investment for shareholders. As shown in Graph 5, the gold price has performed very well over the past 50 years. When analysing Graph 4 and Graph 5, South Africa is economically losing out as the gold price is reasonable, but our gold production is not where it should be.

As shown in Figure 5, in the two industries where unions play a significant role, the consequences of their parts are evident. The damaging effect that unions play in the manufacturing and mining sectors requires urgent intervention. Manufacturing has moved from contributing 22% of our annual GDP to 13%; and mining has moved from being a 21% contributor to a mere 8% (StatsSA, 2017).

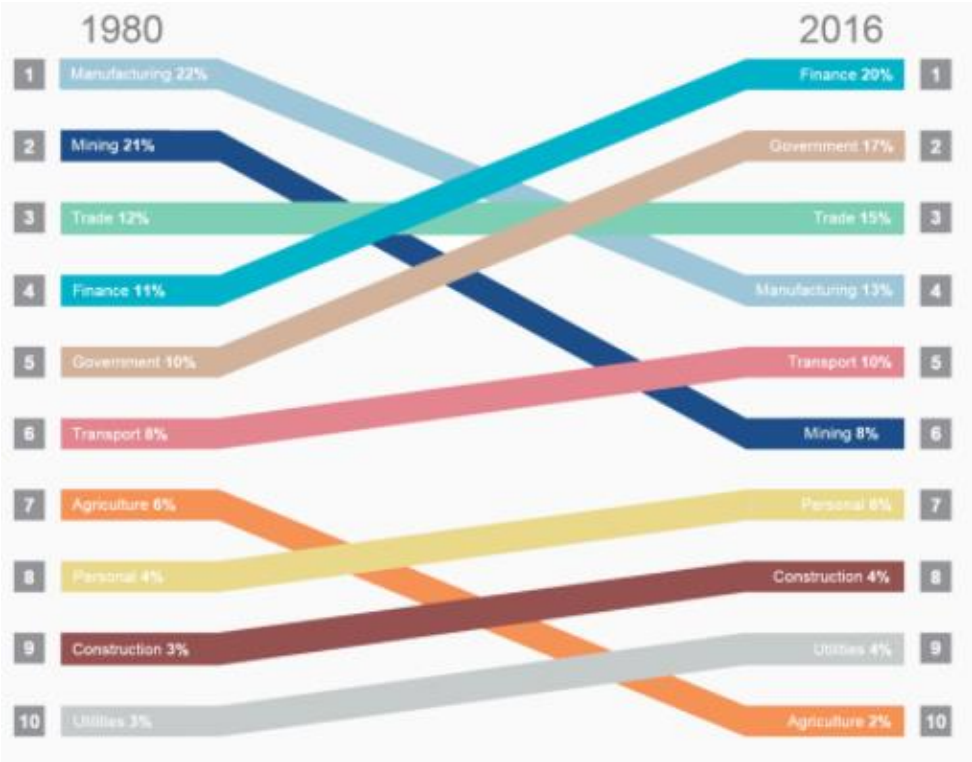


Figure 5: The decline of mining and manufacturing in South Africa **(StatsSA, 2017)**

This study aims to determine the potential benefits of an Earned Value Management (EVM) approach on ongoing-capital-development (OCD) and stoping areas. An EVM approach is used mainly on capital projects and still needs to find its place within working costs. Finding a methodology for managing a mines' performance better within the operational cost could help secure better stakeholder value.

South Africa's gold-mining industry must determine why it lost its competitive advantage when comparing production performances to the rest of the world. The reasons may be depleted orebodies, unproductive workforce, old technology, union involvement, or poor management. For this study, the focus is on management methodology.

1.3 PROBLEM STATEMENT

1.3.1 Operational cost management (Rand)

The achievements of the operational cost expenditure versus the approved budget is an area of concern as it is believed that the duration of the cycle may be too short (currently twelve months) or is bound to be a too-small portion of the total scope of work. A trend of over expenditure and underperformance was noted during the researchers past twenty-five years while consulting on more the twenty mines. For the purpose of the demonstration of this effect, a specific mines data are used to analyse and determine the outcome of both the schedule and cost variances. Mining operational costs are approved annually, and the extent of any deviations during a specific year does not reflect the effect throughout the remainder of the mining operation. Overspending annually is easily overseen as the new year will bring a new budget that will not consider the previous year's poor achievements. The account holders are only responsible for one year's expenditure achievement and not the complete scope deliverable. The compound effect is never taken into consideration from one year to another.

1.3.2 Production performance (Metres, tonnes & m^2)

The same concern raised within the operational cost management is evident in the production performance. Mining production activities are also managed annually. If poor production achievements were achieved versus its planned targets, the underachievement would be written off, and the net effect it caused in the larger plan is never dealt with.

The two main areas that are applicable are:

I. Ongoing-capital-development (OCD) – This activity establishes new tunnels to the reef horizons. The purpose is to create new routes to give men and material access to the mining area (stope – see below). If the ore extraction (stoping) starts later than planned due to these ends being late, the gold production will be late, and value is destroyed. The OCD tunnels are designed and measured in metres. The achievements are measured monthly by surveyors and logged into a database. These ends are usually 3m high and 3m wide and can be more than 5 kilometres long. With the rock density of 2.78 tonnes per m^3 taken into consideration, each metre developed (9 m^3) produces 25.02 tonnes of ore to be transported to the surface.

II. Stoping – Stoping is the terminology used for the mining of the ore-bearing area. The OCD ends are the route to these mining areas. As mentioned above, this activity may start later than planned due to delays in OCD areas, and the revenue loss can compound if the same challenge occurs and production targets are not achieved.

The OCD and stoping areas can cause significant financial losses due to unmet targets, which requires mitigation. Underperforming in these areas is easily overseen as the new year will bring along a new set of targets that will not consider the previous year's poor achievements. The compound effect is never taken into consideration from one year to another.

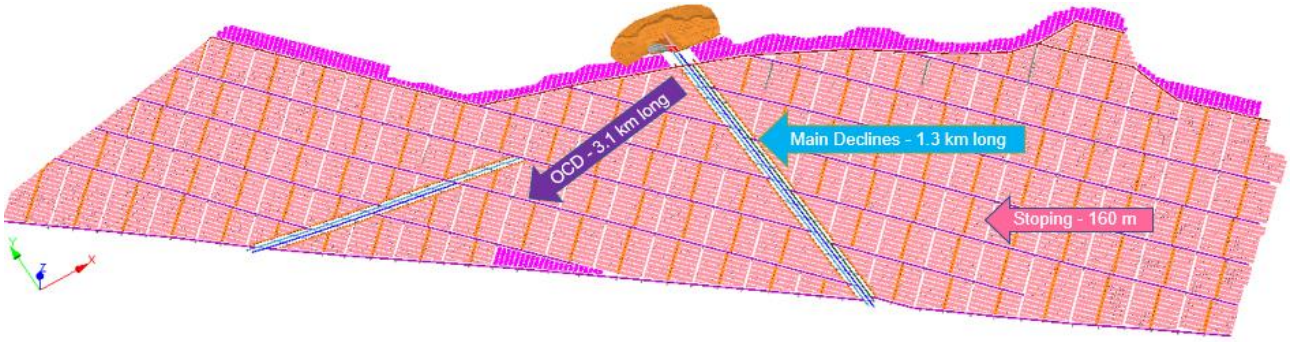


Figure 6: Sefateng mine layout **(Cornish, 2015)**

In Figure 6 (stoping panels – pink), the delayed production on the stoping can be understood if OCD production is late. In this example, the marked OCD end is 3.1 km long and scheduled at an advance of 60 metres per month. If all goes according to plan, it will take 4.3 years to reach the mining operations on the western side. Each OCD metre not achieved will cause the stoping of a specific block to be late. The same scenario will be if the stoping at 160m from the bottom to the top level occurs.

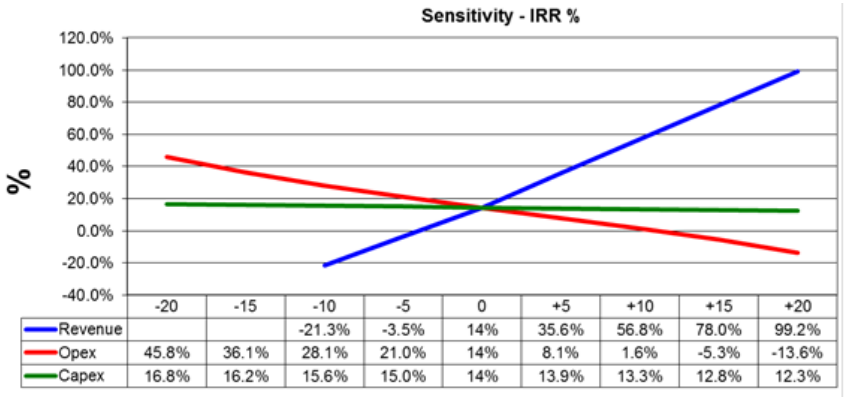
The problem investigated in this study is the mines production performances that may be underperforming and the associated costs that may be overspending.
With the available historical data of the abovementioned problem statement, the data will be used to determine whether the application of EVM on operational cost can enhance profitability in the mining sector. This study will evaluate if EVM can:

- ensure better production achievements;
- increase the effectiveness of cost management;

- proactively forecast cost and production trends; and
- increase the profitability of the organisation.

When comparing the operating cost to any other expense on a mining project, the following is evident:

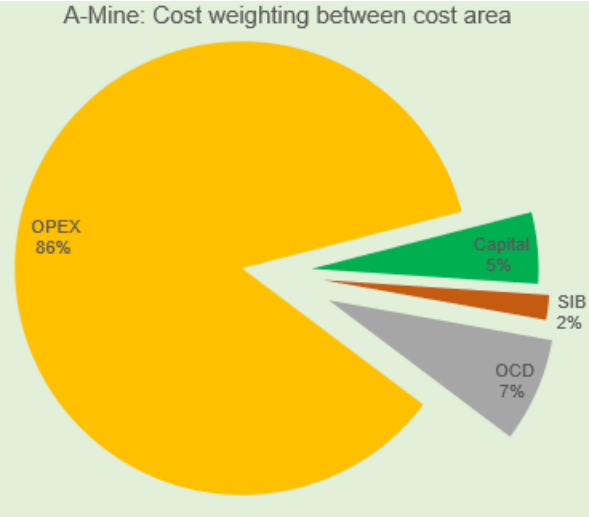
- Operating cost has a higher sensitivity risk than capital, as can be seen in Graph 6. This higher risk means that the effect of overspending working cost targets will corrode the committed financial return promised to investors. There is thus less room for error when compared to capital. In contemplation of the sensitivity analyses, the impact of improved cost and value management could be considerable. Graph 6 is from a feasibility study previously done for A-Mine. The evaluation reflects that if the expenditure is 5% more than planned, the effect will be -5.9% on the IRR (14% to 8.1%). On the positive side, if the expenditure is 5% less, the effect will increase by 7% (14 % to 21%).



	-20	-15	-10	-5	0	+5	+10	+15	+20
Revenue			-21.3%	-3.5%	14%	35.6%	56.8%	78.0%	99.2%
Opex	45.8%	36.1%	28.1%	21.0%	14%	8.1%	1.6%	-5.3%	-13.6%
Capex	16.8%	16.2%	15.6%	15.0%	14%	13.9%	13.3%	12.8%	12.3%

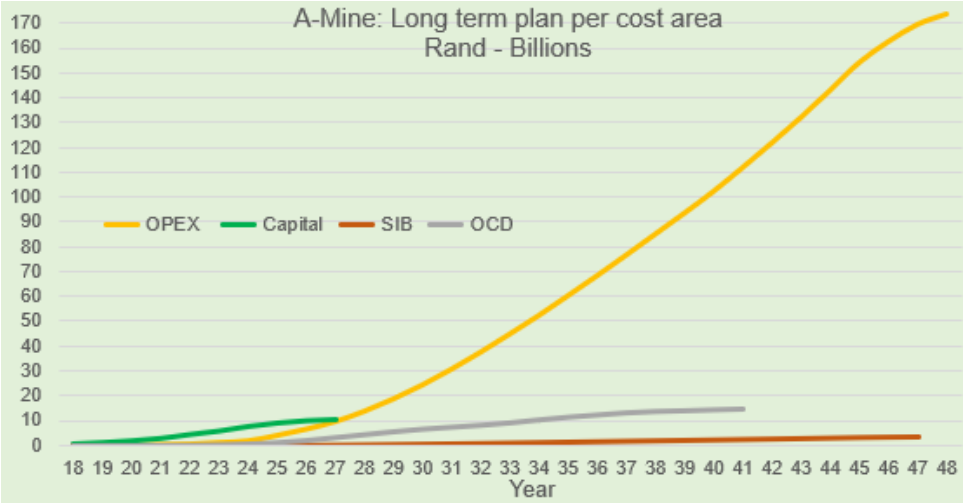
Graph 6: Sensitivity analysis (A-Mine)

- Operating cost attracts the highest monetary value, as can be seen in Graph 7.



Graph 7: Cost weighting between various areas (A-Mine)

- The operating cost has the most extended scheduled duration seen in Graph 8. Capital funding creates infrastructure to open the ore body. Once in production, the operational cost will be made available to pay for mining operations.



Graph 8: Cost forecast per area (A-Mine)

The opportunity lies in the operational cost and OCD areas by implementing project management tools over extended periods. This strategy will ensure production personnel are responsible for larger mining production targets and reflect on the current status of a specific area within the more extensive plans.

With the available information, this research will determine the following:

- Is the operating cost being managed to the best of the mine's ability?
- Are the current methods used effectively?

- Will there be any benefit in managing the cost and production by using EVM?

Mining houses' problem is that the operating cost areas are managed and measured year-to-year. The under-performance on production and over-expenditure just for convenience's sake is forgotten and swept under the carpet.

As illustrated in Table 2, the example shows the challenge and opportunity that must be addressed in the operational and OCD areas. This study will determine if a problem exists concerning the performance of stoping and OCD areas and how the expenditure compares with the achieved performance. If the outcome indicates the need for better tools, this study will illustrate the benefits of using EVM. An EVM approach may solve this issue of integrating the scope with its cost and schedule, and it can pro-actively determine the current cost and production profile in the future based on the actual achievements now. Accountants and planners can take corrective action only if they understand where it is required; EVM will reflect on these high-risk areas, whether cost or schedule.

Table 2: Illustration of impact on underperformance and overspending

			Year 1	Year 2	Year 3	Year 4
Plan	Year 1	18 000 000	360 m x R 50,000 / m			
	Year 2	18 900 000		360 m x R 52,500 / m		
	Year 3	19 845 000			360 m x R 55,125 / m	
Planned		**56 745 000**			Planned completion date	
Actual	Year 1	17 875 000	325 m x R 55,000 / m			
	Year 2	18 768 750		325 m x R 57,750 / m		
	Year 3	19 708 000			325 m x R 60,640 / m	
	Year 4	7 007 700				
Achievement		**63 359 450**		Actual Completion date - 4 months behind schedule		
				Actual Expenditure - R 6.6 mil over budget		

1.4 RESEARCH OBJECTIVES

The main objective of this research is to demonstrate the effectiveness of using EVM on working cost activities by comparing production and cost figures using traditional and EVM costing scenarios. The following specific research objectives will support this:

- to understand the essence of EVM as a cost management tool through a literature study,

- to compare OPEX calculations based on traditional and EVM approaches using historical figures, and
- to create an OPEX dashboard using the EVM approach.

Specific objectives in this research focus on the following:

- Breaking down the operational cost at a higher but more adequate level of control.
- Creating a dashboard by showing the ease of reporting and visibility of variance results.
- Focusing on more extended budget and planning life cycles and abandoning short-term (12 months) plans.

The cost activities should be scheduled over a longer period and the progressive reporting should be reported by the mines Snr accountant and mine planner. Budget cycles must be prepared by these budget holders to ensure it is set-up for earned Value management purposes. This means that all scope, cost and schedules are integrated into one system.

1.5 HYPOTHESIS

The importance of this contribution will be to identify the positive contribution using EVM on working costs can make to the overall strategy of making a mine more successful and sustainable. The goal is to demonstrate the level of impact the implementation of EVM can have when implemented as a management strategy.

The benefits that are demonstrated through this study is that by using EVM, the mine will:

- decrease its operating cost expenditure (increase efficiencies);
- increase its production rates due to better focus on the bigger picture; and
- increase profitability.

Essentially, EVM allows the user to work smarter and not harder.

The question also needs to be asked, why the need for this research?
The answer, in short, is:

- This research can become a game-changer in the mining industry.
- Using EVM can create real value for all stakeholders.

- EVM is a proven management strategy. EVM has not found its place yet in all management structures as the perception is that it is only a project management tool.

Table 3: Demonstration of the importance of each deliverable

	Year 1												Year 2												Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
Area 1	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	240
Area 2	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	240
Area 3	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	240
Area 4	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	240
Area 5	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	240
Total	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	1 200

The demonstration in Table 3 reflects the importance of each deliverable within the larger picture. Each area on its own, if overspent or under-produced, influences the total deliverable. Although a unit of 10 is insignificant compared to an entire scope of 1,200 units on its own, it remains 0.83% of the complete area.

When a production section completes the year and has underperformed by, for instance, 10% and has simultaneously overspent its budget by 10%, the effect of this performance on the following years' plan is not captured.

As seen in Graph 6, the operating cost has a significant impact on the promised returns made to investors using net present value (NPV), Internal rate of return (IRR) and payback periods (Pinkasovitch, 2021). Not controlling the total cost and production packages throughout the area is an imperfect system that does not ensure investors' assets are protected and the actual value for their investment may not be achieved.

Alternative strategies must be determined and used to create better value for all stakeholders and minimise the risk of failure.

1.6 VALIDITY AND DEPENDABILITY

Audited production plans, cost budgets and actual achievements are made available by A-Mine for the study. Mine planners compile the production business plans (BP) by using specialised software and data models. These plans were presented to the organisations'

executives and have been approved. The actual achievements of these production areas were measured by qualified surveyors and approved by the mine's Mineral Resource Manager. The cost accountants calculate the financial business plan (BP) and determine the production profile's cost. An accounting system captures all financial transactions and expenditures. The financial manager and the organisations' auditors verify the achievements.

From a dependability point of view with regards to the author's background to conduct the study is because:

- it falls within the researchers' skills and knowledge;
- the researcher has 25 years of experience on projects and 29 years in the mining field;
- this area is where real change can be implemented; and
- this area has the lowest level of effort, yet it can have maximum impact.

1.7 CONSTRAINTS

Ideally, this study should be done in detail where specific detailed levels can be exposed. Unfortunately, due to the time and data made available by the mines personnel and the limitation on social interaction on the premises of the mine due to Covid-19 regulations, a decision was made to conduct the study in a higher level of detail than initially anticipated.

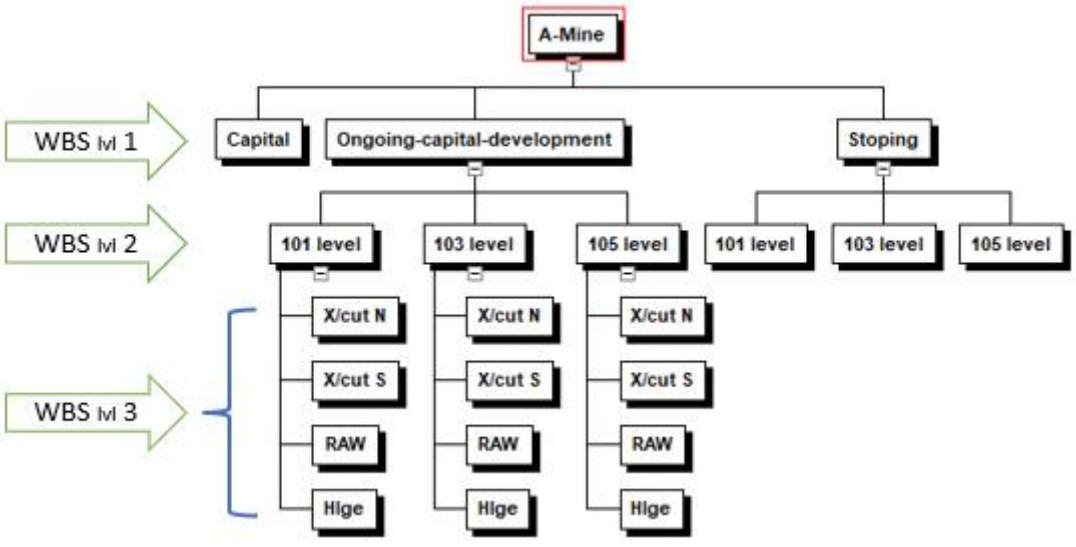


Figure 7: Illustration on level of activities

The ideal level of activity is illustrated in Figure 7 as lvl 3. The information and data used were on a summary level 1. The information remains adequate to determine and demonstrate the outcome. The challenge may be that the net effect is small, but on analysing the detail, certain areas are further from the mark but not shown in summary due to better performance by other areas. The effect will not be visible on a summarised level. An illustration of studying a summarised sample is demonstrated in Table 4.

Table 4: Illustration of summarised sample challenge

	Production plan						
	1	2	3	4	5	6	Total
Area 1	30	30	30	30	30	30	180
Area 2	30	30	30	30	30	30	180
Total	60	60	60	60	60	60	360

	Production achievement						
	1	2	3	4	5	6	Total
Area 1	25	25	25	25	25	25	150
Area 2	35	35	35	35	35	35	210
Total	60	60	60	60	60	60	360

Although the total value reflects that all is on target on the summarised level, one area may compensate for the other's poor performance, causing a misleading reality.

1.8 ENGAGEMENT WITH MINE PERSONNEL

The following ethical principles were followed when engaging with the mine personnel:

- Principle 1 – Minimising the risk of harm.
    - Social disadvantage – I will be cautious when errors in the data are found so that the people responsible for this work do not feel threatened. A very diplomatic approach will be required.
    - Invasion of participants' privacy – Data collected, and information shared will be handled with strict confidentiality.
- Principle 2 – Obtaining informed consent.
    - I have initiated a kick-off meeting with all relevant stakeholders of this research. Written consent has been obtained from the mine's corporate office.
- Principle 3 – Protecting anonymity and confidentiality. The conditions of management's approval will be observed.
    - All data will be kept confidential,
    - All discussions (formal and informal) with personnel will be kept confidential.

- Principle 4 – Avoid deceptive practices.
    - Personnel supplying me with the data will be aware of what they are doing, why they are doing this, and what study results may be.
    - I will remain objective with no preference to what the research outcome may be,
    - All data will be integrated into an EVM system.
- Principle 5 – Providing the right to withdraw.
    - I have ensured the organisation that they may withdraw at any time.

1.9 CHAPTER SUMMARY

Gold mines have played an essential role in the economy of South Africa. It has created not only wealth for a few but has been a means of income for millions of South Africans over the past century. Because of gold, our country's infrastructure was built, and a striving economy was established. South African miners were seen as the best miners in the world. This research wants to give back to the mining community. I will be delighted if a method exists that may help produce for a while longer, keeping a breadwinner for an additional year or two on the payroll.

2 CHAPTER 2 – LITERATURE AND DATA REVIEW

2.1 INTRODUCTION

This chapter will conduct a literature review on Earned Value Management and the benefits thereof. Further to this, the data provided by A-Mine will be reviewed.

A consolidated database with the data received from the mine was constructed and compiled into a structured template to determine the results.

2.2 LITERATURE REVIEW ON EARNED VALUE MANAGEMENT

Earned Value Management is a cost-engineering tool that combines any deliverable's scope, time, and money. Cost engineering applies scientific principles and techniques to estimation problems, cost control, business planning and management science, profitability analysis, project management, and planning and scheduling (AACEI, 2021).

Figure 8: Cost Engineering triangle **(Eby, 2021)**

Earned Value Management requires four fundamental control concepts. They are (Services, 2020):

- The concept of a project. Defines the scope of work to be achieved and sets parameters.
- The concept of cost engineering.
- The concept of a Work Breakdown Structure (WBS). Used to decompose the scope of work of the project into manageable elements.

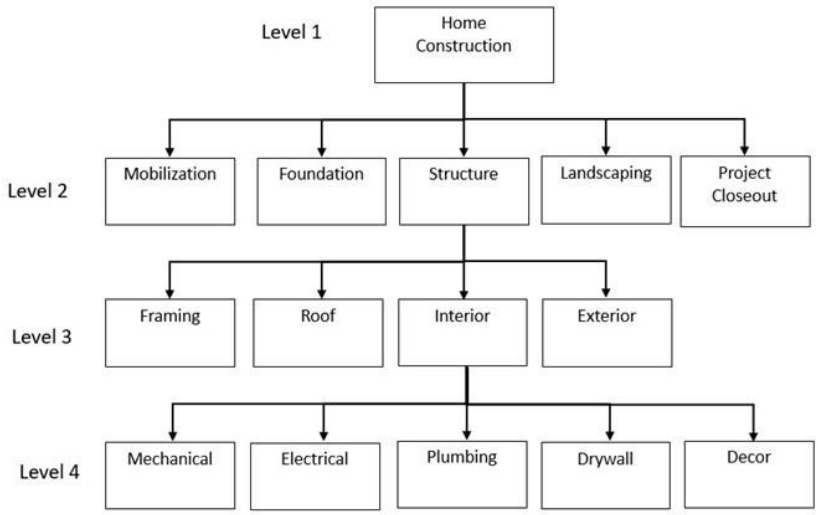


Figure 9: WBS Example **(Wondershare, 2021)**

- The concept of project scheduling.

The USA department of defence initiated EVM in 1967 (Consulting, 2021). The concept was named the Cost/Schedule Control Systems Criteria Policy. The governing body of project managers, Project Management Institute (PMI) (Fostel, 2011), included EVM in the very first copy of their PMBOK (Project Management Body of Knowledge) during 1987. The Project Management Body of Knowledge guide is PMI's flagship publication and is a fundamental resource for effective project management in any industry (Guide, 2021). The Project Management Body of Knowledge guide notes EVM as being crucial for scope and cost management.

2.2.1 Earned Value Management methodology

Earned Value Management is a management methodology that incorporates any program. This methodology offers all levels of management with early visibility into cost and time-related problems. Earned Value Management helps provide the basis to assess work progress against a baseline plan, relates technical, time and cost performance, provides data for pro-active management action and provides managers with a summary of effective decision making (International, 2017).

The important names and acronyms used in EVM are (Reader, 2020):

- PV - Planned Value (BCWS: Budgeted Cost of Work Scheduled). Approved budget for work scheduled to be completed by a specific date).

- AC - Actual Cost (ACWP: Actual Cost of Work Performed). Actual cost realised for the work performed on a particular activity during a specific period).
- EV - Earned Value (BCWP: Budgeted Cost of Work Performed). Amount of completed work presented as the value of the performance budget allocated to that work).
- BAC - Budget at Completion. The sum of the total budgets that are expected to be spent on the performed work.
- SV - Schedule Variance. Difference between where we planned to be and where we are actually on the schedule.
- CV - Cost Variance. Difference between what was planned to spend and what was paid.
- SPR - Schedule Performance Ratio. Shows the rate at which the project performance meets schedule expectations up to a specific point.
- CPR - Cost Performance Ratio. The rate at which project performance is meeting planned costs during a particular period.
- EAC - Estimate at Completion. Shows the estimated total cost when completing all tasks.
- ETC - Estimate to Complete. It shows how much money it will need to finish the outstanding tasks of the project.

2.2.2 Earned Value Management formulas

Earned Value Management uses many different formulas to determine various outcomes of the project.

The following are the main formulas (Reader, 2020):

- BAC = Total Project Budget.
- EV = BAC x % Complete.
- SV = EV – PV.
- SPR = EV/PV.

- CPR = EV/AC
- SV = EV - PV
- CV = EV – AC
- EAC = BAC / CPR
  = AC + BAC - EV
  = AC = ETC
  = AC+ [(BAC-EV) (SPR x CPR)]
- ETC = EAC-AC
- VAC = BAC-EAC

For this study, the main formulas used are the calculation of EAC (Estimate at Completion).

2.2.3 Earned Value Management benefits

Earned Value Management offers more information than standard project tracing. It proactively answers the following questions immediately (International, 2017):

- Are we on the path where we need to be in the project?
- When will we finish the project?

It helps define where we are currently in the project and calculates a forecast on a completion date and duration remaining at current performance.

The value-added method helps achieve greater visibility and control of the project's activities, which helps take action to issues early on, thus making it possible to meet the project timelines. It gives clear interaction of the activities involved and enhances project visibility and responsibility.

The fundamental basis of EVM is that the value of the portion of work is equal to the number of funds budgeted to achieve it.

2.3 LITERATURE REVIEW AND DATA ANALYSIS ON PRODUCTION PLANNING

2.3.1 Background

In the mining sector, four primary cost allocations exist. They are:

i. Capital — Funds sourced from investors to establish the following:
    - Greenfields projects – New endeavours where no mining previously occurred.
    - Brownfields projects – Existing operations where projects are initiated for the following purposes:
        - Expansion project – The purpose is to expand the current infrastructure to increase mining capacity to realise a higher production profile.
        - Replacement project – The purpose is to enable the current infrastructure to sustain the mining production profile longer than initially planned.
        - OCD – Ongoing-capital-development to establish new mining horizons to unmined production levels.

ii. Sustaining capital - Capital paid to ensure safety is not compromised and investment in keeping the integrity of the mine's infrastructure.

iii. Operational cost – The costs provided that day-to-day mining activities are done to ensure production targets. This cost includes direct and indirect costs.

Three sets of planning documents were handed over for review and analysis. These documents form the basis of all planning parameters for the mine’s total production and financial planning over the remaining life of the mine. This planning also determines the comprehensive resources required monthly. It gives a state where the mine will no longer be profitable or need mitigations to push it through difficult years where a production gap (gold gap) may occur until orebodies are opened up.

The documents used for data review are:

i. Capital monthly pack – Detail of all capital requirements.

ii. Finance review pack – Detail of all operational cost requirements

iii. Ore reserve management (ORM) review pack – Detail of all production deliverables requirements. The ORM planning includes the planning of capital and operating costs.

This study will mainly focus on the OCD and stoping planning in the "ORM review pack" and the financial planning of these areas in the "Finance review pack". These three files

include a lot of detail, and a summary has been compiled with the assistance of the A-Mine's Snr Accountant.

This research will focus on ongoing-capital-development and stoping, which are included in points ii and iii above.
All areas that are seen in the ORM review pack are values derived from geological reports.

2.3.2 OCD review

The summarised information for the OCD was taken from the detailed and monthly plan received from A-Mine's Snr Accountant.

2.3.2.1 Production plans and achievements

The ongoing-capital-development production plans with actual achievements can be seen in Table 5 and Table 6. These development ends are, on average, 3m wide and 3m high. The main focus is only on the development and not on other costs such as Secondary Support, Raiseboring etc.

Table 5: OCD production plans vs achievements – Monthly (A-Mine)

	2018												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
Budget BP 2018	792	1 038	1 015	957	987	943	931	790	870	915	850	740	**10 828**
Actual 2018	394	760	377	895	673	614	953	733	706	897	620	645	**8 266**

	2019												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
Budget BP 2018	645	834	716	733	616	752	793	795	790	785	823	805	**9 086**
Actual 2019	415	869	876	786	766	775	1 175	849	836	842	849	882	**9 919**

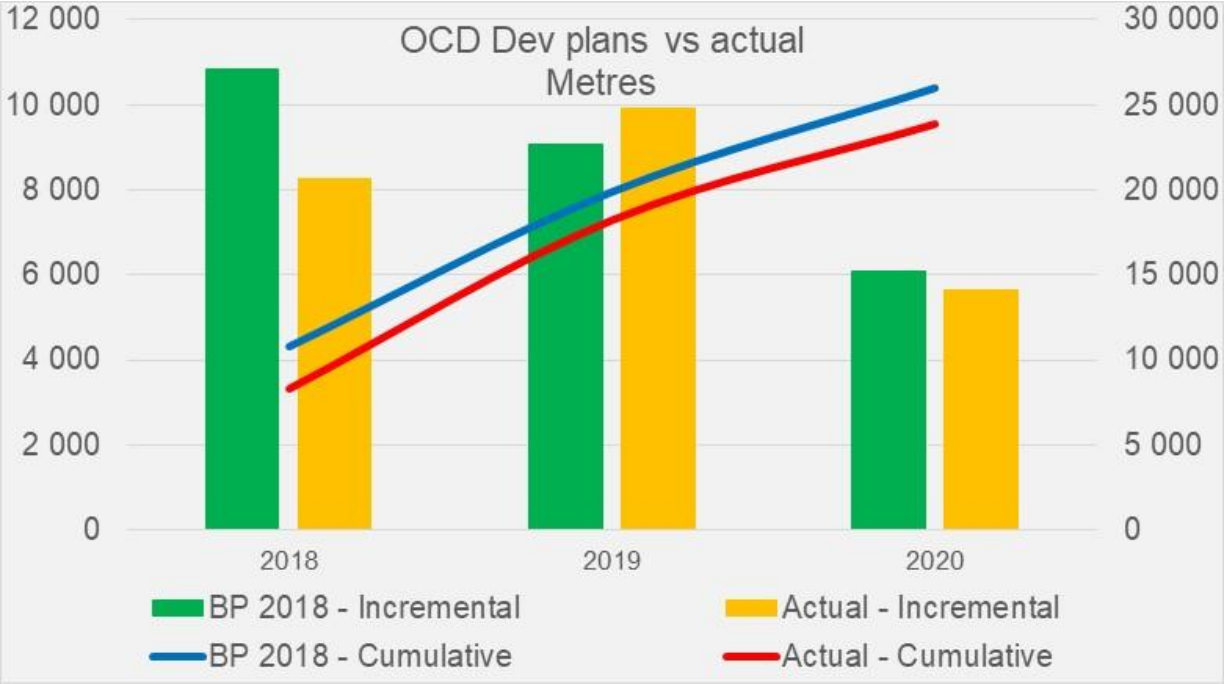
	2020												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
Budget BP 2018	466	704	749	233	-	254	249	672	665	699	667	732	**6 089**
Actual 2020	351	737	570	196	-	166	374	470	641	711	714	719	**5 648**

The poor results during April and May 2020 was due to Covid-19. For this study, a flex (Tools, 2021) budget was used during this period to ensure that the variances were not overstated.

Table 6: OCD production plans vs achievements – Yearly (A-Mine)

	2018	2019	2020
BP 2018 - Incremental	10 828	9 086	6 089
Actual - Incremental	8 266	9 919	5 648
BP 2018 - Cumulative	10 828	19 914	26 003
Actual - Cumulative	8 266	18 185	23 833

Although the impact of Covid-19 can be seen during 2020s total achievements, the purpose of this study remains focused on more extended periods, and 2018 reflects this.



Graph 9: OCD production plans vs achievements - Yearly (A-Mine)

Production shows a below-planned actual achievement when making a comparison on a cumulative basis. This study's purpose is to address this and demonstrate how EVM can assist in managing this challenge.

2.3.2.2 Budget plans and achievements

It is visible that a good focus is on the cost management of the production.

Table 7: OCD budget plans vs achievements – Monthly (A-Mine)

	2018											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Budget BP 2018	38 062 083	41 545 700	42 397 639	40 560 736	40 315 643	40 192 059	30 493 127	29 627 920	30 050 979	30 471 714	30 411 800	28 358 455
Actual 2018	34 807 843	35 735 147	30 371 808	27 448 920	28 474 000	24 224 004	27 875 192	31 309 542	26 954 846	32 090 711	27 491 623	31 070 090

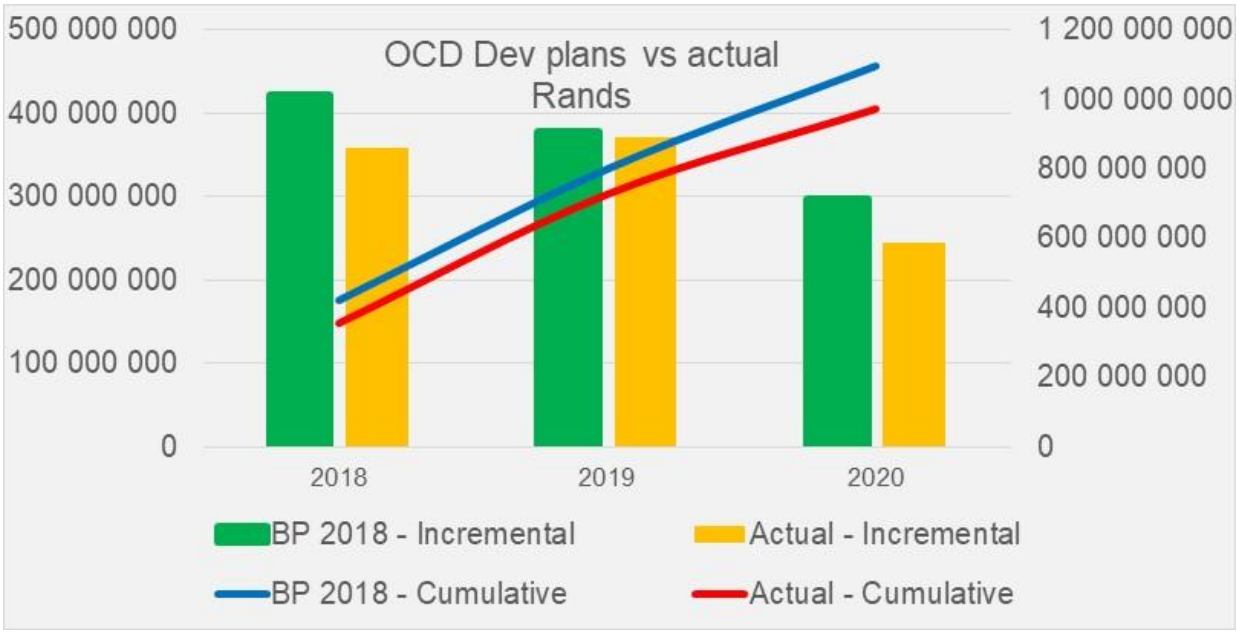
	2019											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Budget BP 2018	28 515 589	30 423 412	29 325 446	28 181 234	27 602 618	27 290 938	33 925 618	35 920 976	34 147 437	35 002 757	34 828 094	33 632 261
Actual 2019	26 079 137	29 654 579	30 773 641	29 331 091	29 271 647	30 871 439	33 927 086	35 701 810	34 206 665	32 420 558	29 884 447	27 872 192

	2020											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Budget BP 2018	30 627 402	33 364 830	33 732 850	11 868 346	-	12 913 284	12 677 491	32 766 933	32 011 867	33 250 084	31 840 557	31 579 357
Actual 2020	25 659 821	29 749 326	29 523 249	-	-	5 237 364	11 703 873	22 326 862	28 253 902	30 355 211	29 732 314	31 999 074

Although no actual expenditure was reported over the Covid-19 lockdown period (April – July 2020), a small portion of the development was done during April (196m). The financial budget was also flexed as per the development production.

Table 8: OCD budget plans vs achievements – Yearly (A-Mine)

	2018	2019	2020
BP 2018 - Incremental	422 487 855	378 796 379	296 632 999
Actual - Incremental	357 853 725	369 994 291	244 540 997
BP 2018 - Cumulative	422 487 855	801 284 234	1 097 917 233
Actual - Cumulative	357 853 725	727 848 016	972 389 012

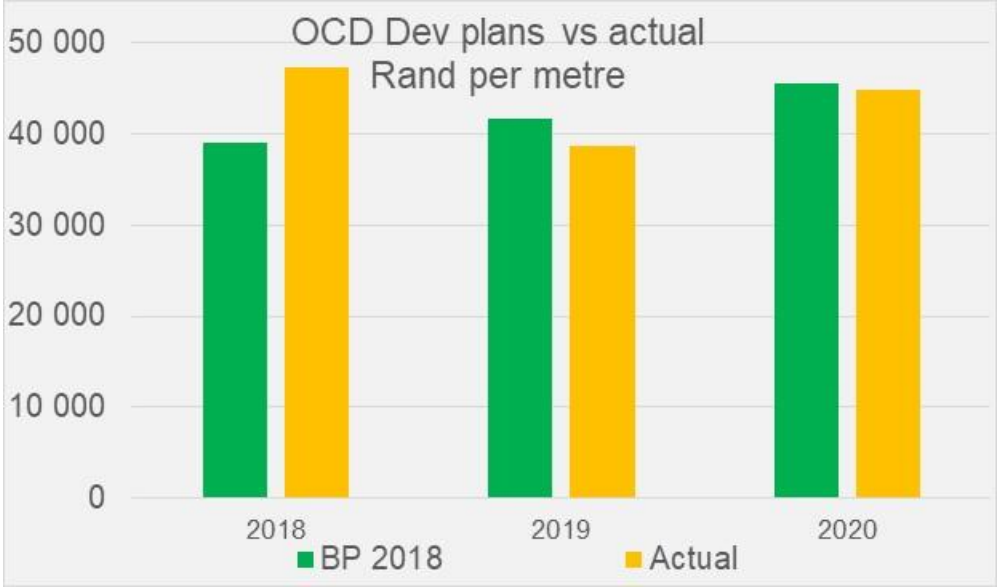


Graph 10: OCD budget plans vs achievements - Yearly (A-Mine)

2.3.2.3 OCD efficiencies

Table 9: OCD Rand per Metre achievement (A-Mine)

	2018	2019	2020
BP 2018	38 992	41 762	45 526
Actual	47 241	38 723	44 858



Graph 11: OCD Rand per Metre achievement (A-Mine)

2.3.3 Stoping review

The summarised information for the stoping was taken from the detailed and monthly plan received from A-Mine's Snr Accountant. The stoping budget was also adjusted with a flex value as per the OCD development. This budget caters for more realistic targets over the challenging lockdown period during Covid-19 in 2020.

2.3.3.1 Production plans and achievements

Table 10: Stoping production plans vs achievements – Monthly (A-Mine)

	2018											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Budget BP 2018	6 816	10 074	10 848	9 258	11 569	11 376	11 271	10 522	10 772	11 332	10 909	10 734
Actual 2018	5 802	11 798	5 728	13 274	11 772	11 661	13 521	10 439	11 355	13 624	9 028	12 624

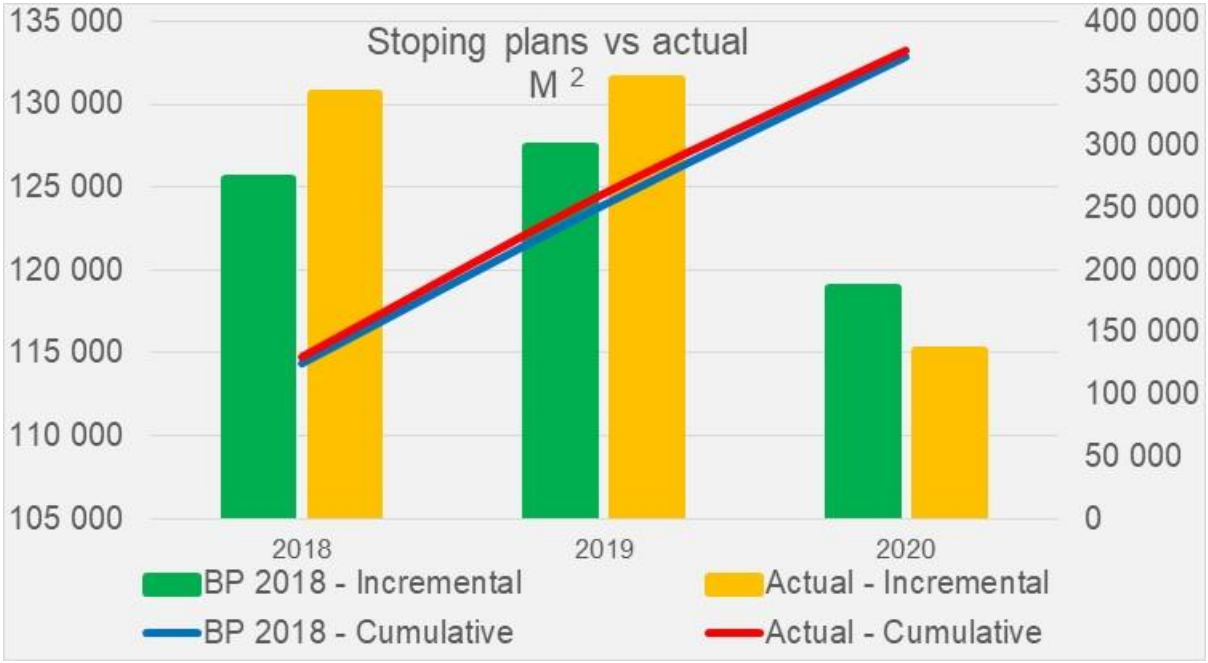
	2019											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Budget BP 2018	6 628	10 877	11 410	9 303	9 571	11 001	11 309	11 136	11 071	11 134	11 859	12 123
Actual 2019	8 506	10 912	10 607	8 996	10 344	10 552	12 519	12 393	11 633	11 062	11 110	12 869

	2020											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Budget BP 2018	7 244	10 933	12 086	6 077	6 420	6 568	6 977	11 913	12 136	12 497	13 125	12 961
Actual 2020	6 462	11 228	9 839	4 149	7 285	7 369	7 325	10 024	14 320	13 162	10 986	13 007

A-Mine's labour force was not allowed to be on 100% during the lockdown period during April – July 2020. The stoping achievements are evidence of this.

Table 11: Stoping production plans vs achievements – Yearly (A-Mine)

	2018	2019	2020
BP 2018 - Incremental	125 482	127 422	118 937
Actual - Incremental	130 626	131 503	115 156
BP 2018 - Cumulative	125 482	252 904	371 841
Actual - Cumulative	130 626	262 129	377 285



Graph 12: Stoping production plans vs achievements – Yearly (A-Mine)

2.3.3.2 Budget plans and achievements

Table 12: Stoping budget plans vs achievements – Monthly (A-Mine)

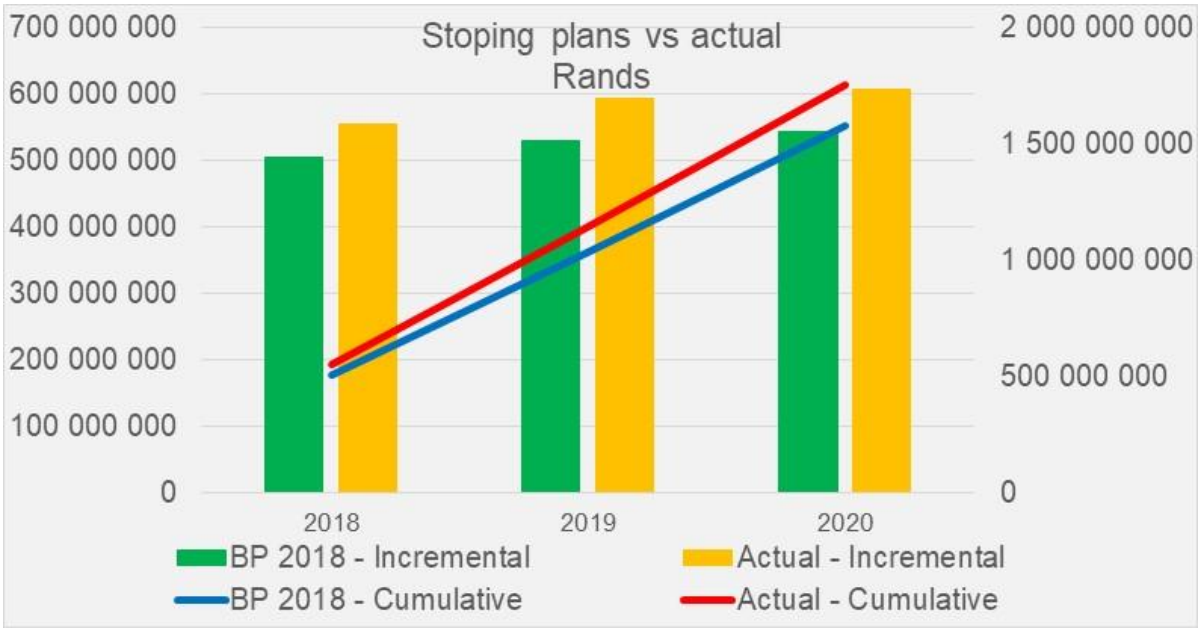
	2018											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Budget BP 2018	40 233 377	43 046 053	44 584 902	42 906 514	44 537 649	44 983 403	40 746 634	41 607 004	40 623 479	41 646 594	40 254 653	40 358 844
Actual 2018	44 039 566	45 629 575	45 821 549	40 526 394	46 138 609	45 212 859	47 520 654	50 475 936	44 612 013	53 097 369	45 644 361	45 130 028

	2019											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Budget BP 2018	37 960 840	40 766 754	41 659 055	39 515 443	39 863 004	41 256 616	48 734 274	47 952 258	48 043 032	47 634 268	47 284 010	48 960 841
Actual 2019	55 442 214	49 465 725	45 561 964	47 924 598	48 341 150	47 959 754	52 767 609	53 212 330	47 136 767	48 257 779	48 902 679	47 211 329

	2020											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Budget BP 2018	45 811 683	48 251 022	49 749 077	28 879 990	30 508 460	31 212 317	33 156 536	54 620 117	53 809 313	55 206 208	56 126 011	55 224 371
Actual 2020	44 273 831	47 032 756	44 497 555	26 566 564	37 266 790	37 642 744	47 085 486	55 808 033	69 153 236	67 805 757	64 618 913	65 456 462

Table 13: Stoping budget plans vs achievements – Yearly (A-Mine)

	2018	2019	2020
BP 2018 - Incremental	505 529 107	529 630 396	542 555 106
Actual - Incremental	553 848 914	592 183 897	607 208 128
BP 2018 - Cumulative	505 529 107	1 035 159 502	1 577 714 609
Actual - Cumulative	553 848 914	1 146 032 810	1 753 240 938



Graph 13: Stoping budget plans vs achievements – Yearly (A-Mine)

2.3.3.3 Stoping efficiencies

Table 14: Stoping Rand per m^2 achievement (A-Mine)

	2018	2019	2020
BP 2018	4 099	4 212	4 653
Actual	4 593	4 574	5 423

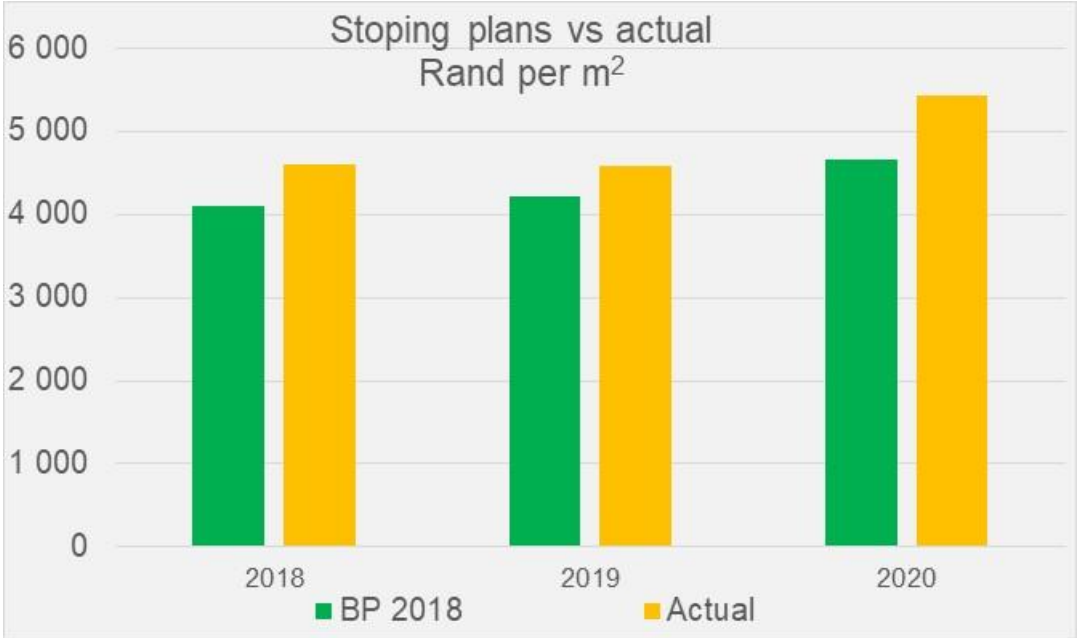


Figure 10: Stoping Rand per m^2 achievement (A-Mine)

2.4 CONCLUSION

2.4.1 EVM literature review

Understanding the principles of EVM is of utmost importance to conduct this study. No evidence was found where EVM is done on operational cost production areas before. This studies purpose is to demonstrate the value that EVM can add to this area of interest. For a successful study, a good understanding of how the mining plans and the execution thereof works and a good understanding of EVM methodology.

2.4.1 A-Mine data review

The content, literature, and data required to do this research and analysis will be the financial and production documents used to determine the various outcomes on the mine's life, which are also sequenced into different levels (approved projects/not approved projects).

This research will mainly focus on the older approved plans as the history will give the study a better understanding of the concerns. The data was made available to me by A-

Mine and are available on soft and hard copy. These documents form part of the mine's long-term strategic planning process. As this information is susceptible, it will remain highly confidential and not be found in the public domain. Mining houses keep their information confidential and would prefer that their competitors do not see it. The available data is adequate for the study.

The topic for the research is fact-based and could not be found to be researched before. Much research has been done on EVM and mining, but no evidence is available on these two integrated.

3 CHAPTER 3 – RESEARCH METHODOLOGY

3.1 RESEARCH DESIGN CLASSIFICATION

The research conducted is classified as a quantitative research design.

The mine's data from the past three years (2018 – 2020) was collected, and a restated document reflecting the planned development targets and the planned budgets for these areas was compiled. A technical, numerical approach was used as the data is cost and schedule orientated.

The cost planning and actual achievement information were made available from the mine's accountant, and the mine planner supplied the production targets and achievement. These parties were not directly involved in the study but merely executed management's decision to supply production and financial data.

The data supplied by the mine form the data set to be analysed. The study determines and demonstrates if a benefit is possible by using EVM on managing cost and production. All planned production with associated costs has been scrutinised and compared with the actual achievements.

All eleven quantitative research processes were affected during the research planned, namely (Thompson, 2017):

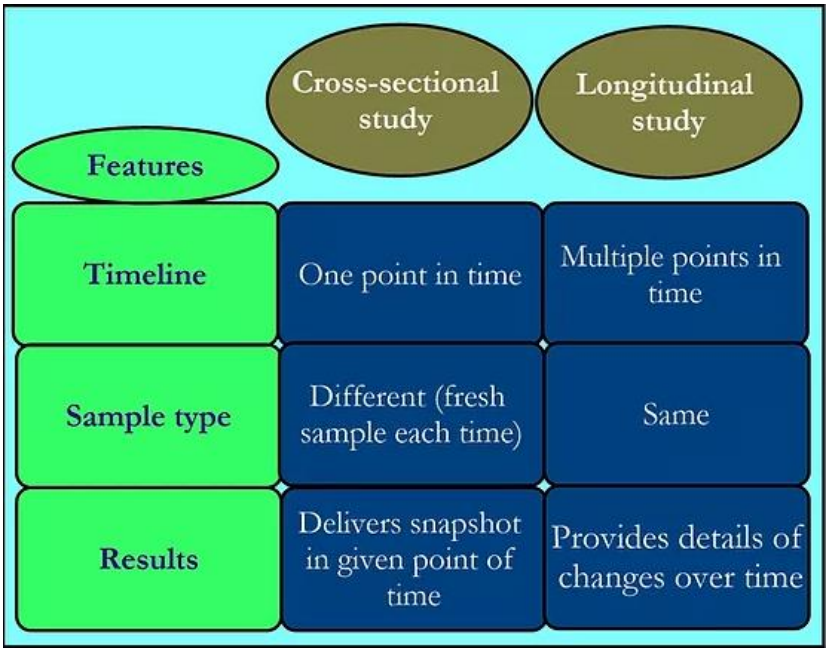
I. Theory
II. Hypothesis
III. Research design
IV. Operationalising concepts
V. Selection of research site
VI. Selection of respondents
VII. Data collection
VIII. Processing data
IX. Data analysis
X. Findings and conclusions
XI. Writing up of results

Further to above, a quantitative research design has been adopted because:

- it offers to focus on the researcher's viewpoint.
- theories and concepts are tested.

- a structured data collection process has been conducted; and
- data are reliable and factual.

Table 15: Cross-sectional vs Longitudinal study **(Akhouri, 2020)**



As shown in Table 5, based on the leading indicators of Cross-sectional and longitudinal, the study is a longitudinal study.

The reasons for conducting a longitudinal study are due to:

- Study timelines over multiple points in time:
    - month
    - year
    - Three years
- The sample type will be the same on all measurements:
    - Production achievements - Metres, m3 or tons (target vs actual)
    - Cost performance - Rands (budget vs actual)
- The results will show the details of its changes over time. The analyses will reflect the cost and production performances on an incremental and cumulative basis.

3.2 METHOD OF DATA IMPLEMENTATION

The study data is databased, investigational, simulated, and sourced from A-Mine. Understanding how the mine conducts its production planning and associated budget

models were required to be understood in detail. Further to the planning process, filtering the correct detailed actual achievements from the production cycle and expenditure achievement required a good knowledge of the data.

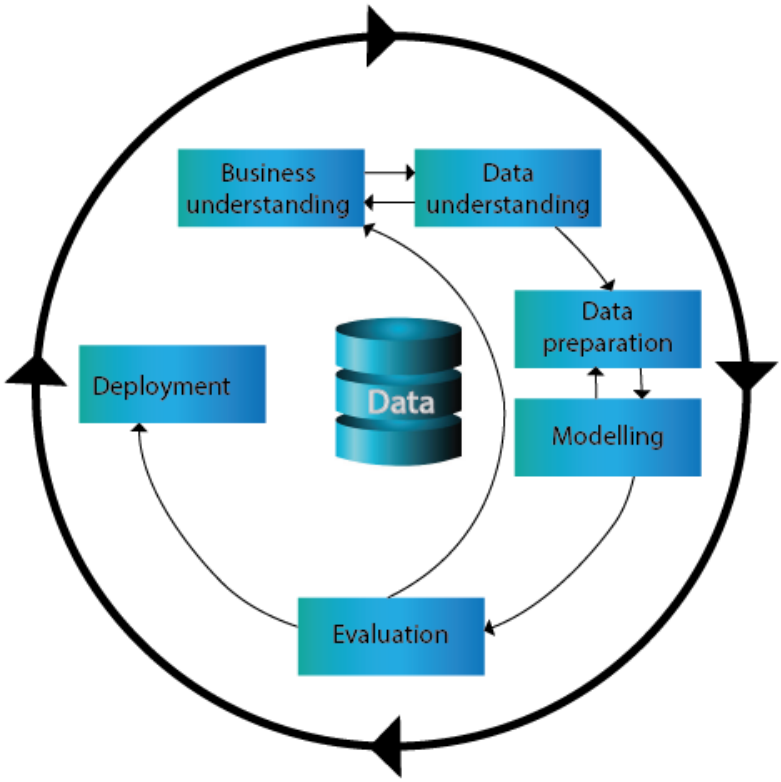
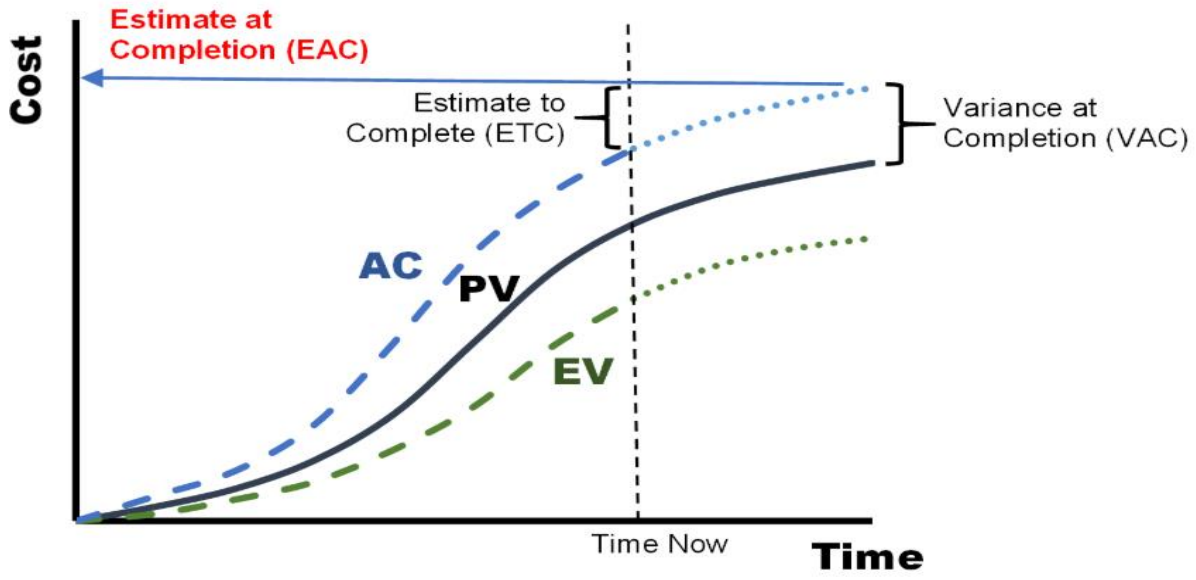


Figure 11: Data implementation process **(Point, 2021)**

The aim was to reflect if, at any given time in the past three years, the Estimate at Completion (EAC) could predict the outcome if the current trend on production and cost (positive or negative) is not corrected. Graph 14 shows an example of EAC. The formula for achieving this result is the following:

EAC = ((Total Planned Value – Earned Value) / Cost Performance Ratio) + Actual Cost



Graph 14: Estimate at completion explanation **(Roseke, 2018)**

The Earned Value and Cost Performance Ratio was measured at a specific time (increments) and varied to establish the particular outcomes.

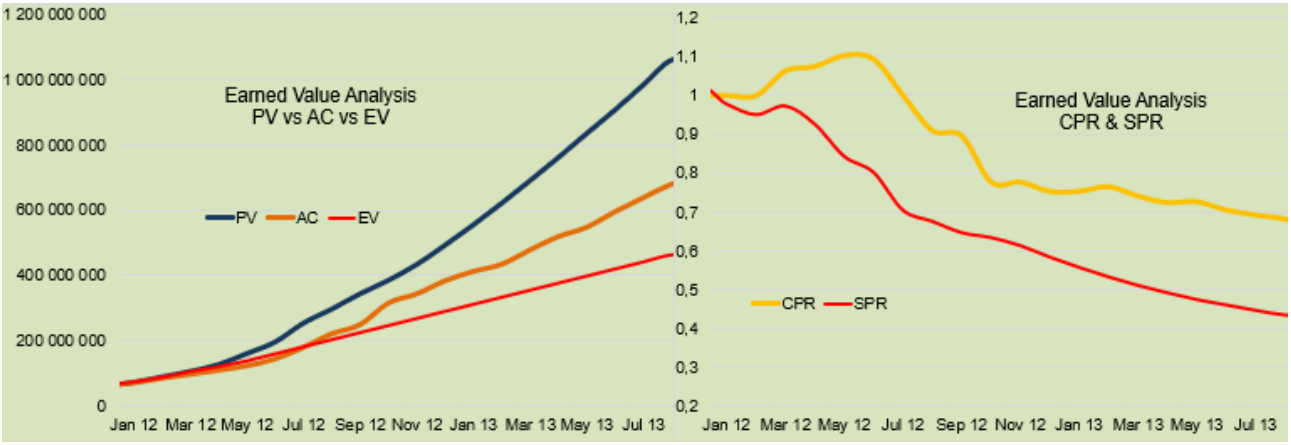
The outcome and deliverables that integrate all the relevant information into EVM will be as per the examples below.

Table 16: EVM example summary (CPR, SPR, CV & SV)

WBS Area	CPR bcwp/acwp	SPR bcwp/bcws	CV bcwp-acwp	SV bcwp-bcws
SH 1 Mining Progress	1,22	1,06	15 682 283	4 879 762
SH 2 Civil Progress	1,26	0,38	1 116 227	(8 860 542)
SH 3 Structural Progress	1,19	0,64	1 039 804	(3 690 758)
SH 5 Mechanical Progress	0,98	1,00	(524 536)	57 787
SH 7 Piping Progress	0,88	0,51	(287 021)	(2 080 529)
SH 8 Electrical Progress	1,00	0,23	5 112	(8 286 960)
SH 9 Instrumentation Progress	0,59	0,10	(145 899)	(1 940 728)
SH 70 Fees Progress	1,38	1,00	2 734 940	0
SH 72 Profesional Services	1,59	1,00	15 078 310	0
SH 90 General Services	1,04	2,06	114 838	1 494 890
Total	**1,18**	**0,91**	**27 689 933**	**(17 905 921)**

Table 17: EVM example summary (PV, EV & AC)

SUMMARY WORK PACKAGE	Original Budget	Planned BCWS (PV) %	Planned BCWS (PV) Rands	Actual BCWP (EV) %	Actual BCWP (EV) Rands	Actual ACWP (AV) %	Actual ACWP (AV) Rands	Indicated Total Cost (EAC) Rands	Variance (EAC vs Budget) Rands
SH 1 Mining Progress	433 995 513	18,7%	81 306 463	19,9%	86 186 225	16,2%	70 503 942	**355 026 509**	**(78 969 005)**
SH 2 Civil Progress	120 176 502	11,8%	14 191 769	4,4%	5 331 227	3,5%	4 215 000	**95 014 509**	**(25 161 992)**
SH 3 Structural Progress	56 711 047	18,2%	10 296 983	11,6%	6 606 226	9,8%	5 566 422	**47 784 867**	**(8 926 181)**
SH 5 Mechanical Progress	167 968 849	14,5%	24 325 636	14,5%	24 383 422	14,8%	24 907 958	**171 582 195**	**3 613 346**
SH 7 Piping Progress	41 010 047	10,3%	4 223 008	5,2%	2 142 478	5,9%	2 429 499	**46 504 031**	**5 493 985**
SH 8 Electrical Progress	53 746 448	19,9%	10 716 024	4,5%	2 429 064	4,5%	2 423 952	**53 633 329**	**(113 119)**
SH 9 Instrumentation Progress	15 482 361	13,9%	2 153 151	1,4%	212 423	2,3%	358 322	**26 116 178**	**10 633 817**
SH 10 Consumable Progress	2 403 296	14,1%	338 098	0,4%	8 444	0,0%	1	**270**	**(2 403 025)**
SH 70 Fees Progress	67 801 501	14,8%	10 004 140	14,8%	10 004 140	10,7%	7 269 200	**49 265 870**	**(18 535 631)**
SH 72 Profesional Services	135 713 637	29,9%	40 643 560	29,9%	40 643 560	18,8%	25 565 250	**85 365 382**	**(50 348 255)**
SH 90 General Services	7 860 241	18,0%	1 413 254	37,0%	2 908 144	35,5%	2 793 305	**7 549 852**	**(310 390)**
Working Cost Development	124 396 837	1,2%	1 496 384	1,9%	2 347 194	7,6%	9 479 763	**113 082 356**	**(11 314 481)**
Sub-Total	**1 227 266 278**	**16,4%**	**201 108 470**	**14,9%**	**183 202 548**	**12,7%**	**155 512 615**	**1041 772 563**	**(185 493 715)**



Graph 15: EVM example Graphs (PV, AC & EV)

To conclude, the aim was to determine the following with all relevant data received:

i. PV – Planned Value (Determine the monetary value of the planned and scheduled production over the pre-determined duration).

ii. EV – Earned Value. Calculate the actual monitory value of work performed/achieved.

iii. AC – Actual Cost. Include the actual expenditure to the correct allocated scope of work.

iv. CV – Cost Variance. Determine what the deviation between the earned work and actual expenditure is.

v. SV – Schedule Variance. Determine the deviation between the earned work and the actual plan.

vi. CPR – Cost Performance Ratio. A ratio above 1 indicates that earned work is done at a lower cost than planned, and a ratio less than 1 suggests an over-expenditure on earned work performed.

vii. SPR – Schedule Performance Ratio. A ratio above 1 indicates that earned work is ahead of the planned schedule, and a ratio less than 1 indicates an underachievement on the schedule on earned work performed.

viii. EAC – Estimate at Completion. The final estimated cost if the current performance remains.

ix. SAC – Schedule at Completion. The duration when the current performance remains. The variance will be in months over or under the original plan.

Since the study involves the analysis of existing data, there is no direct human involvement and no "sampling" in the traditional sense. Data will be made available with the consent of management by those people who are officially in charge of the data.
The personnel who will assist me with the following are:

- Snr Project Manager;
- Snr Accountant; and
- Snr Mine Planner.

This research's objective will establish what benefits or different outcomes Earned Value Management will have if used as a management tool. I, therefore, use historical data as a predictor for future benefits.
Data analysis is defined as "a process of cleaning, transforming, and modelling data to discover useful information for business decision-making. The purpose of data analysis is to extract useful information from data and make the decision based upon the data analysis" (Johnson, 2021).
The validity and reliability of the data are accurate as only audited data will be used.

3.3 AREAS EARMARKED FOR RESEARCH

Mining has a large footprint on the surface as well as underground. The main areas in a typical deep level gold mine are:

- Mine
    - Headgear – Concrete or steel headgear that houses the hoist wheel (sheave).
    - Winders – Mechanical mechanism used transporting men, material, and ore in the shaft barrels up and down.
    - Shaft barrel – As per above and to accommodate all services required underground (air, water, electricity, etc.).
    - Pump stations – Pumping of all water back to surface from underground.
    - Fridge plants – Cooling recirculated water underground to be used to cool mine underground.
    - Access development ends – Forms the "highway" from the shaft to the mining infrastructure.
    - Ongoing-capital-development ends – Forms the routes from the "highway" to access the orebody.
    - Stopes – Reef carrying orebody.
- Surface storage facilities
    - Tailing's storage facility – TSF is a waste product from the gold plant from crushed, milled, and processed rock.
    - Rock dump storage facility – Development on non-reef bearing areas is hoisted to the surface and disposed of here.

The research will be done as per "ongoing-capital-development" and "stopes".

Figure 12: Mine layout (shaft and dev), Rock dump **(Martin, 2021)**, and Tailing storage **(Dreamstime, 2021)**

3.4 ANALYSIS OF DATA

The analysis was done by sourcing the mines BP2018 (business plan 2018), which was compiled and approved during 2017. This data includes all the production plans and associated cost budget for the duration until the mine will not be able to produce gold anymore profitably. This total duration is called a "Long Term Plan" (LTP) or a "Life of Mine" (LOM). The detail is done in annual increments and scheduled accordingly.

Once this LTP is approved, the data for the first three years are detailed, and production plans and monthly cost budgets plans are determined. This study will be using these same three years, which will span over 2018, 2019, and 2020. This study will set up a database with this three-year production plan on OCD and stoping budgets.

From the previous step, I will use the actual performance achievements on the OCD and stoping activities and incorporate them with the original BP 2018, as shown in Table 18.

Table 18: Example of how the study will analyse BP18 with actual achievements

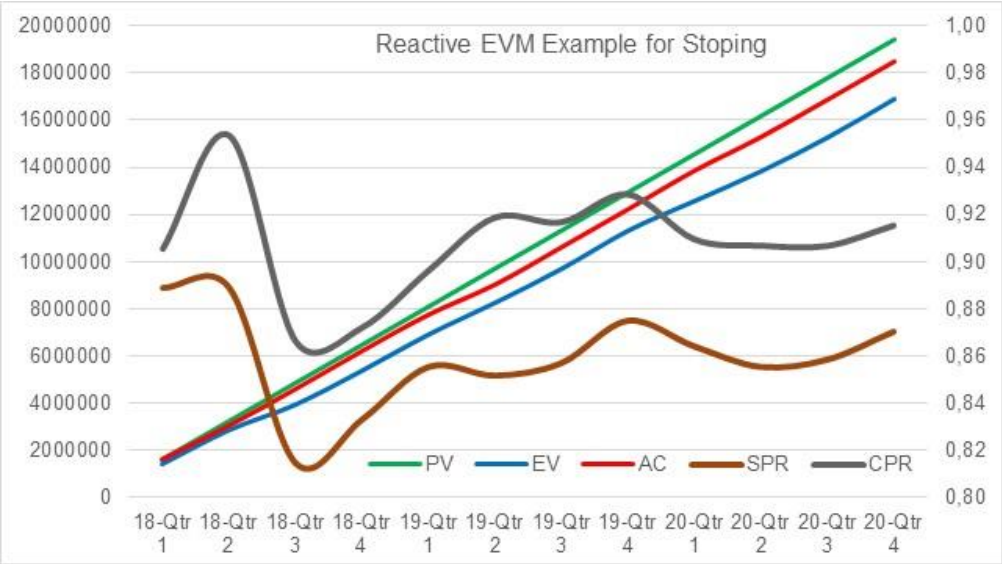
Stoping production plan and actual achievements

	UOM	2018 (Qtrs)				2019 (Qtrs)				2020 (Qtrs)			
Planned - BP18	m	18	18	18	18	18	18	18	18	18	18	18	18
Actual - 2018	m	16	16	12	16								
Actual - 2019	m					17	15	16	18				
Actual - 2020	m									14	14	16	18
Variance - Monthly		-2	-2	-6	-2	-1	-3	-2	0	-4	-4	-2	0
Variance - Cumulative		-2	-4	-10	-12	-13	-16	-18	-18	-22	-26	-28	-28

Stoping cost budget and expenditure

	UOM	2018				2019				2020			
Planned - BP18	R	1 620 000	1 620 000	1 620 000	1 620 000	1 620 000	1 620 000	1 620 000	1 620 000	1 620 000	1 620 000	1 620 000	1 620 000
Actual - 2018	R	1 590 000	1 430 000	1 550 000	1 620 000								
Actual - 2019	R					1 540 000	1 280 000	1 590 000	1 610 000				
Actual - 2020	R									1 640 000	1 430 000	1 590 000	1 610 000
Variance - Monthly		- 30 000	- 190 000	- 70 000	-	- 80 000	- 340 000	- 30 000	- 10 000	20 000	- 190 000	- 30 000	- 10 000
Variance - Cumulative		- 30 000	- 220 000	- 290 000	- 290 000	- 370 000	- 710 000	- 740 000	- 750 000	- 730 000	- 920 000	- 950 000	- 960 000

The researcher will integrate plans and actual performances, and a reactive EVM calculation will be done. This calculation will allow us to play *devil's advocate* by moving around the actual achievements and determining the EAC, and noting how these values would have been from the actual yearly actual expenditures.



Graph 16: EVM Graph as per stoping example in Table 8

3.5 CHAPTER SUMMARY

The impact on a slower than planned OCD and stoping performance can be detrimental to the total success of the mining operations. With high fixed-costs as water, electricity, labour costs, and the maintenance of the dangerous infrastructures' integrity, the mine cannot delay any production. New methodologies should be investigated to ensure better focus.

4 CHAPTER 4 – EMPIRICAL ANALYSIS AND RESULTS

4.1 INTRODUCTION

Due to the sensitive nature of the information, an Excel database was compiled and submitted to A-Mine's Snr Accountant and Snr Mine Planner to populate with the desired information required to conduct the successful study. The following information was received from A-Mine:

- BP2018 (Business plan 2018). Includes the OCD and stoping production and budget plans for 2018, 2019 and 2020.
- OCD production achievements received for 2018, 2019 and 2020.
- OCD actual expenditure received for 2018, 2019 and 2020.
- Stoping production achievements received for 2018, 2019 and 2020.
- Stoping actual expenditure received for 2018, 2019 and 2020.

This information adequately demonstrates this study's intention and how EVM can benefit the operational cost activities.

The intention will be to indicate at any given time in the past three years if the Estimate at Completion (EAC) could calculate the effect if the current trend on production and cost (positive or negative) is not corrected.

As shown in Table 19, the scale will be used as a visual analysis of the specific deviation in the following segment.

Table 19: Deviation scale for areas analysed

	Favourable performance	On budget or better	A visual analyis is used to demonstrate the deviations as per scale
	Unfavourable performance	1% - 5 % deviation	
	Unfavourable performance	5% - 10 % deviation	
	Unfavourable performance	10 % + deviation	

4.2 AREAS ANALYSED

4.2.1 Ongoing-capital-development

The analysis was done on incremental and cumulative plans versus actual achievements on the development and costs. For the study, only the cumulative is shown as this reflects the realistic trends. The total budget over the three years was planned at R 1,097,917,233. Table 20 is the first year of the cumulative ongoing production and cost budget. 2018 will focus on months 01 – 12 of this program.

Table 20: OCD – 2018 EVM Analysis + EAC

	Jan 18	Feb 18	Mar 18	Apr 18	May 18	Jun 18	Jul 18	Aug 18	Sep 18	Oct 18	Nov 18	Dec 18
Planned metres	792	1830	2845	3802	4789	5732	6663	7453	8323	9238	10088	10828
Actual metres	394	1154	1531	2426	3099	3713	4666	5398	6104	7001	7621	8266
Planned cost	38062083	79607783	122005422	162566158	202881802	243073861	273566988	303194907	333245886	363717600	394129400	422487855
Actual cost	34807843	70542990	100914798	128363718	156837718	181061722	208936914	240246456	267201302	299292012	326783635	357853725
Planned rate / metre	48049	43501	42879	42756	42362	42406	41056	40681	40038	39371	39069	39018
Actual rate / metre	88390	61119	65906	52909	50608	48766	44781	44505	43777	42749	42881	43293
PV	38062083	79607783	122005422	162566158	202881802	243073861	273566988	303194907	333245886	363717600	394129400	422487855
EV	18921795	50208595	65655583	103731125	131283313	157450127	191555036	219604589	244380129	275642332	297734378	322512823
AC	34807843	70542990	100914798	128363718	156837718	181061722	208936914	240246456	267201302	299292012	326783635	357853725
SV	- 19140288	- 29399188	- 56349840	- 58835033	- 71598488	- 85623734	- 82011952	- 83590319	- 88865757	- 88075268	- 96395022	- 99975032
CV	- 15886048	- 20334396	- 35259216	- 24632593	- 25554405	- 23611595	- 17381878	- 20641867	- 22821172	- 23649681	- 29049258	- 35340902
SPR	0,50	0,63	0,54	0,64	0,65	0,65	0,70	0,72	0,73	0,76	0,76	0,76
CPR	0,54	0,71	0,65	0,81	0,84	0,87	0,92	0,91	0,91	0,92	0,91	0,90
EAC	2019688457	1542571844	1687535044	1358635012	1311627727	1262563508	1197543240	1201116634	1200445038	1192116814	1205038489	1218226823
Var EAC vs Budget	921771224	444654611	589617811	260717780	213710494	164646275	99626007	103199401	102527805	94199581	107121256	120309590
% Variance forecast	46%	29%	35%	19%	16%	13%	8%	9%	9%	8%	9%	10%

OCD Cost analysis as of Dec 2018

During 2018 (the first year of the three-year investigation), the development fell behind 2,562 m (-23.6%). The total cost was underspent with R 64,634,130 million (-15.3%). The EVM calculations show a 0.90 CPR and 0.76 SPR. Using the CPR to calculate the

Estimate at Completion, EVM at the end of 2018 forecast if the current performance and cost trend remains, the total approved cost budget of R 1,097,917,233 can be overspent with R 120,309,590.

Table 21: OCD – 2018 Schedule at Completion forecast

	Jan 18	Feb 18	Mar 18	Apr 18	May 18	Jun 18	Jul 18	Aug 18	Sep 18	Oct 18	Nov 18	Dec 18
Total PV	1097 917 233	1097 917 233	1097 917 233	1097 917 233	1097 917 233	1097 917 233	1097 917 233	1097 917 233	1097 917 233	1097 917 233	1097 917 233	1097 917 233
EAC	2 019 688 457	1542 571 844	1687 535 044	1358 635 012	1311 627 727	1262 563 508	1197 543 240	1201 116 634	1200 445 038	1192 116 814	1205 038 489	1218 226 823
Planned Shedule	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0
Schedule at completion	72,4	57,1	66,9	56,4	55,6	55,6	51,4	49,7	49,1	47,5	47,7	47,2
Month variance	36,4	21,1	30,9	20,4	19,6	19,6	15,4	13,7	13,1	11,5	11,7	11,2
	Jan 18	Feb 18	Mar 18	Apr 18	May 18	Jun 18	Jul 18	Aug 18	Sep 18	Oct 18	Nov 18	Dec 18
Elaps Time (Since start	1,0	2,0	3,0	4,0	5,0	6,0	7,0	8,0	9,0	10,0	11,0	12,0
Total months	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0
x (Days x SPR)	0,5	1,3	1,6	2,6	3,2	3,9	4,9	5,8	6,6	7,6	8,3	9,2
y	35,5	34,7	34,4	33,4	32,8	32,1	31,1	30,2	29,4	28,4	27,7	26,8
Total months forecast	72,4	57,1	66,9	56,4	55,6	55,6	51,4	49,7	49,1	47,5	47,7	47,2
Total Months Over/Under	36,4	21,1	30,9	20,4	19,6	19,6	15,4	13,7	13,1	11,5	11,7	11,2
% Variance forecast	50%	37%	46%	36%	35%	35%	30%	28%	27%	24%	24%	24%

OCD Schedule analysis as of Dec 2018

Using the SPR to calculate the Schedule at Completion in Table 21, EVM at the end of 2018 forecast if the current performance and cost trend remains, the total development planned to be completed within 36 months may take 11.2 months longer than planned. The late arrival at new mining areas will be disastrous. As explained previously, this development creates a path to new orebodies; 11.2 months can equate to hundreds of gold kilograms lost over the intended production period.

Table 22 is a cumulative ongoing production and cost budget. 2019 will focus on months 13 – 24.

Table 22: OCD – 2019 EVM Analysis + EAC

	Jan 19	Feb 19	Mar 19	Apr 19	May 19	Jun 19	Jul 19	Aug 19	Sep 19	Oct 19	Nov 19	Dec 19
Planned metres	11 474	12 307	13 023	13 756	14 372	15 124	15 917	16 712	17 502	18 287	19 109	19 914
Actual metres	8 681	9 549	10 425	11 212	11 978	12 753	13 928	14 777	15 613	16 455	17 303	18 185
Planned cost	451 003 444	481 426 856	510 752 302	538 933 536	566 536 154	593 827 092	627 752 710	663 673 685	697 821 122	732 823 879	767 651 973	801 284 234
Actual cost	383 932 862	413 587 441	444 361 082	473 692 172	502 963 819	533 835 258	567 762 344	603 464 154	637 670 819	670 091 377	699 975 823	727 848 016
Planned rate / metre	39 308	39 117	39 218	39 178	39 420	39 264	39 438	39 712	39 871	40 074	40 172	40 238
Actual rate / metre	44 229	43 312	42 623	42 250	41 991	41 860	40 763	40 838	40 843	40 724	40 454	40 025
PV	451 003 444	481 426 856	510 752 302	538 933 536	566 536 154	593 827 092	627 752 710	663 673 685	697 821 122	732 823 879	767 651 973	801 284 234
EV	341 217 134	373 529 290	408 865 603	439 244 759	472 166 789	500 735 149	549 306 724	586 826 879	622 487 662	659 400 493	695 101 623	731 721 010
AC	383 932 862	413 587 441	444 361 082	473 692 172	502 963 819	533 835 258	567 762 344	603 464 154	637 670 819	670 091 377	699 975 823	727 848 016
SV	- 109 786 310	- 107 897 566	- 101 886 699	- 99 688 777	- 94 369 365	- 93 091 943	- 78 445 985	- 76 846 806	- 75 333 460	- 73 423 386	- 72 550 350	- 69 563 224
CV	- 42 715 728	- 40 058 151	- 35 495 478	- 34 447 414	- 30 797 030	- 33 100 109	- 18 455 620	- 16 637 275	- 15 183 157	- 10 690 884	- 4 874 200	3 872 995
SPR	0,76	0,78	0,80	0,82	0,83	0,84	0,88	0,88	0,89	0,90	0,91	0,91
CPR	0,89	0,90	0,92	0,93	0,94	0,94	0,97	0,97	0,98	0,98	0,99	1,01
EAC	1 235 361 484	1 215 660 433	1 193 232 410	1 184 020 500	1 169 528 771	1 170 492 885	1 134 805 081	1 129 044 557	1 124 696 639	1 115 717 805	1 105 616 062	1 092 105 964
Var EAC vs Budget	137 444 251	117 743 201	95 315 177	86 103 267	71 611 538	72 575 652	36 887 848	31 127 324	26 779 407	17 800 572	7 698 829	- 5 811 269
% Variance forecast	11%	10%	8%	7%	6%	6%	3%	3%	2%	2%	1%	-1%

OCD Cost analysis as of Dec 2019

During 2018 – 2019 (the first two years of the three-year investigation), the development fell behind 1,729 m (-8.7%), as seen in Table 22. Some of the deficit metres were caught up. The total cost was now underspent by R 69,563,224 million (-8.7%). The EVM calculations show a 1.01 CPR and 0.91 SPR. Using the CPR to calculate the Estimate at Completion, EVM at the end of 2019 forecast if the current performance and cost trend remains, the total approved cost budget of R 1,097,917,233 can be underspent with R 5,811,269. The mine accountants and development teams made a great effort by the production and cost team this year.

Table 23: OCD – 2019 Schedule at Completion forecast

	Jan 19	Feb 19	Mar 19	Apr 19	May 19	Jun 19	Jul 19	Aug 19	Sep 19	Oct 19	Nov 19	Dec 19
Total PV	1097 917 233	1097 917 233	1097 917 233	1097 917 233	1097 917 233	1097 917 233	1097 917 233	1097 917 233	1097 917 233	1097 917 233	1097 917 233	1097 917 233
EAC	1235 361 484	1215 660 433	1193 232 410	1184 020 500	1169 528 771	1170 492 885	1134 805 081	1129 044 557	1124 696 639	1115 717 805	1105 616 062	1092 105 964
Planned Shedule	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0
Schedule at completion	47,6	46,4	45,0	44,2	43,2	42,7	41,1	40,7	40,4	40,0	39,8	39,4
Month variance	11,6	10,4	9,0	8,2	7,2	6,7	5,1	4,7	4,4	4,0	3,8	3,4
	Jan 19	Feb 19	Mar 19	Apr 19	May 19	Jun 19	Jul 19	Aug 19	Sep 19	Oct 19	Nov 19	Dec 19
Elaps Time (Since start	13,0	14,0	15,0	16,0	17,0	18,0	19,0	20,0	21,0	22,0	23,0	24,0
Total months	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0
x (Days x SPR)	9,8	10,9	12,0	13,0	14,2	15,2	16,6	17,7	18,7	19,8	20,8	21,9
y	26,2	25,1	24,0	23,0	21,8	20,8	19,4	18,3	17,3	16,2	15,2	14,1
Total months forecast	47,6	46,4	45,0	44,2	43,2	42,7	41,1	40,7	40,4	40,0	39,8	39,4
Total Months Over/Under	11,6	10,4	9,0	8,2	7,2	6,7	5,1	4,7	4,4	4,0	3,8	3,4
% Variance forecast	24%	22%	20%	18%	17%	16%	12%	12%	11%	10%	9%	9%

OCD Schedule analysis as of Dec 2019

Using the SPR to calculate the Schedule at Completion in Table 23, EVM at the end of the 2018 – 2019 (the first two years of the three-year investigation) forecast if the current performance and cost trend remains, the total development planned to be completed within 36 months may take 3.4 months longer than planned. Production performance has closed the initial forecast completion duration with 7.8 months.

Table 24 is a cumulative ongoing production and cost budget. 2020 will focus on months 25 – 36.

Table 24: OCD – 2020 EVM Analysis + EAC

	Jan 20	Feb 20	Mar 20	Apr 20	May 20	Jun 20	Jul 20	Aug 20	Sep 20	Oct 20	Nov 20	Dec 20
Planned metres	20 380	21 084	21 832	22 065	22 065	22 319	22 568	23 240	23 905	24 603	25 271	26 003
Actual metres	18 536	19 273	19 843	20 039	20 039	20 205	20 579	21 049	21 689	22 400	23 114	23 833
Planned cost	831 911 636	865 276 466	899 009 315	910 877 661	910 877 661	923 790 944	936 468 435	969 235 368	1001 247 235	1034 497 320	1066 337 876	1097 917 233
Actual cost	753 507 837	783 257 163	812 780 412	812 780 412	812 780 412	818 017 776	829 721 649	852 048 511	880 302 413	910 657 624	940 389 938	972 389 012
Planned rate / metre	40 820	41 040	41 178	41 281	41 281	41 391	41 496	41 706	41 885	42 047	42 197	42 223
Actual rate / metre	40 651	40 640	40 960	40 560	40 560	40 486	40 319	40 480	40 587	40 654	40 686	40 800
PV	831 911 636	865 276 466	899 009 315	910 877 661	910 877 661	923 790 944	936 468 435	969 235 368	1001 247 235	1034 497 320	1066 337 876	1097 917 233
EV	756 636 397	790 972 334	817 100 209	827 232 044	827 228 295	836 297 059	853 939 602	877 853 457	908 450 413	941 847 553	975 322 465	1006 302 442
AC	753 507 837	783 257 163	812 780 412	812 780 412	812 780 412	818 017 776	829 721 649	852 048 511	880 302 413	910 657 624	940 389 938	972 389 012
SV	- 75 275 239	- 74 304 131	- 81 909 106	- 83 645 617	- 83 649 366	- 87 493 885	- 82 528 834	- 91 381 911	- 92 796 822	- 92 649 767	- 91 015 411	- 91 614 791
CV	3 128 560	7 715 171	4 319 796	14 451 632	14 447 883	18 279 283	24 217 953	25 804 947	28 148 000	31 189 929	34 932 527	33 913 430
SPR	0,91	0,91	0,91	0,91	0,91	0,91	0,91	0,91	0,91	0,91	0,91	0,92
CPR	1,00	1,01	1,01	1,02	1,02	1,02	1,03	1,03	1,03	1,03	1,04	1,03
EAC	1093 377 536	1087 208 111	1092 112 830	1078 736 768	1078 741 657	1073 919 612	1066 780 010	1065 643 400	1063 898 673	1061 558 949	1058 593 804	1060 916 290
Var EAC vs Budget	- 4 539 697	- 10 709 122	- 5 804 403	- 19 180 465	- 19 175 576	- 23 997 621	- 31 137 223	- 32 273 833	- 34 018 560	- 36 358 284	- 39 323 429	- 37 000 943
% Variance forecast	0%	-1%	-1%	-2%	-2%	-2%	-3%	-3%	-3%	-3%	-4%	-3%

OCD Cost analysis as of Dec 2020

During 2018 – 2020 (the total planned program), the development ended behind 2,170 m (-8.4%). The total cost was now underspent by R 125,528,221 (-11.4%). The EVM calculations show a CPR of 1.03 and an SPR of 0.92.

The final summary shows an actual cost of over R 972,389,012, and development achieved realised an Earned Value of R 1,006,302,012. Although the work done was less than planned (EV vs PV), a cost-saving of R 33,913,430 was achieved over this period.

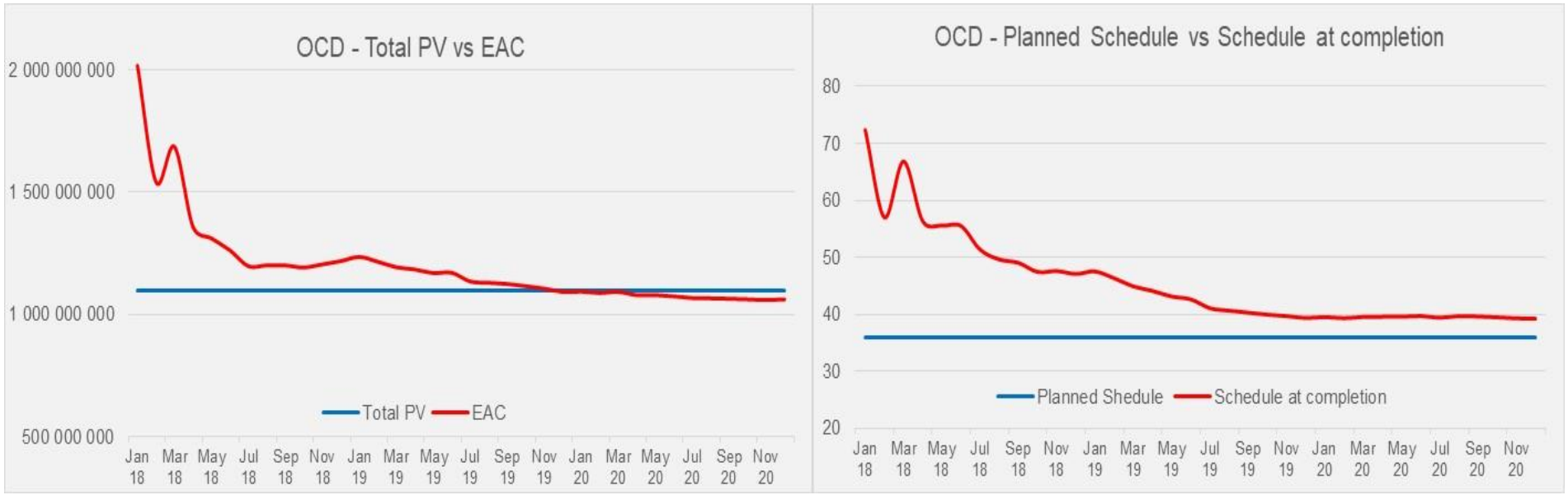
Table 25: OCD – 2020 Schedule at Completion forecast

	Jan 20	Feb 20	Mar 20	Apr 20	May 20	Jun 20	Jul 20	Aug 20	Sep 20	Oct 20	Nov 20	Dec 20
Total PV	1097 917 233	1097 917 233	1097 917 233	1097 917 233	1097 917 233	1097 917 233	1097 917 233	1097 917 233	1097 917 233	1097 917 233	1097 917 233	1097 917 233
EAC	1093 377 536	1087 208 111	1092 112 830	1078 736 768	1078 741 657	1073 919 612	1066 780 010	1065 643 400	1063 898 673	1061 558 949	1058 593 804	1060 916 290
Planned Shedule	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0
Schedule at completion	39,6	39,4	39,6	39,6	39,6	39,8	39,5	39,7	39,7	39,5	39,4	39,3
Month variance	3,6	3,4	3,6	3,6	3,6	3,8	3,5	3,7	3,7	3,5	3,4	3,3

	Jan 20	Feb 20	Mar 20	Apr 20	May 20	Jun 20	Jul 20	Aug 20	Sep 20	Oct 20	Nov 20	Dec 20
Elaps Time (Since start	25,0	26,0	27,0	28,0	29,0	30,0	31,0	32,0	33,0	34,0	35,0	36,0
Total months	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0
x (Days x SPR)	22,7	23,8	24,5	25,4	26,3	27,2	28,3	29,0	29,9	31,0	32,0	33,0
y	13,3	12,2	11,5	10,6	9,7	8,8	7,7	7,0	6,1	5,0	4,0	3,0
Total months forecast	39,6	39,4	39,6	39,6	39,6	39,8	39,5	39,7	39,7	39,5	39,4	39,3
Total Months Over/Under	3,6	3,4	3,6	3,6	3,6	3,8	3,5	3,7	3,7	3,5	3,4	3,3
% Variance forecast	9%	9%	9%	9%	9%	9%	9%	9%	9%	9%	9%	8%

OCD Schedule analysis as of Dec 2020

With the underperformance of 2,170m development over the 36 months, SPR was used to calculate the Schedule at Completion in Table 25. The EVM calculations at the end of the 2018 – 2020 forecast that due to the slower than planned achievements, the scheduled amount of metres planned initially will only be 3.3 months later.



Graph 17: OCD PV vs EAC & PS vs Schedule at Completion

Graph 17 shows the total EAC vs the original planned total budget as it progressed over the 36 months. The schedule at completion also reflects the forecast months the period may extend if the SPR did not increase.

Graph 18: OCD Earned Value Analysis

As seen in Graph 18, the PV wasn't achieved over this period. The final EVM analysis was as follows:

PV: R 1,907,917,233

EV: R 1,006,302,402

AC: R 972,389,012

SV:- R 91,614,791 The less work done than initially planned equates to this value.

CV: R 33,913,430

4.2.2 Stoping

The analysis was done on incremental and cumulative plans versus actual achievements on the stoping and costs. For this study, only the cumulative is shown as this reflects the realistic trends. The total budget over the three years was planned at R 1,577,714,609. Table 26 is the first year of the cumulative ongoing production and cost budget. 2018 will focus on months 01 – 12 of this program.

Table 26: Stoping – 2018 EVM Analysis + EAC

	2018											
	Jan 18	Feb 18	Mar 18	Apr 18	May 18	Jun 18	Jul 18	Aug 18	Sep 18	Oct 18	Nov 18	Dec 18
Planned m^2	6 816	16 890	27 738	36 996	48 565	59 941	71 212	81 734	92 507	103 839	114 748	125 482
Actual m^2	5 802	17 600	23 328	36 602	48 374	60 035	73 556	83 995	95 350	108 974	118 002	130 626
Planned cost	40 233 377	83 279 430	127 864 333	170 770 847	215 308 496	260 291 899	301 038 532	342 645 537	383 269 016	424 915 610	465 170 263	505 529 107
Actual cost	44 039 566	89 669 141	135 490 691	176 017 084	222 155 693	267 368 553	314 889 206	365 365 142	409 977 156	463 074 525	508 718 886	553 848 914
Planned rate / m^2	5 903	4 931	4 610	4 616	4 433	4 342	4 227	4 192	4 143	4 092	4 054	4 029
Actual rate / m^2	7 590	5 095	5 808	4 809	4 592	4 454	4 281	4 350	4 300	4 249	4 311	4 240
PV	40 233 377	83 279 430	127 864 333	170 770 847	215 308 496	260 291 899	301 038 532	342 645 537	383 269 016	424 915 610	465 170 263	505 529 107
EV	34 247 954	86 780 223	107 535 480	168 952 172	214 461 714	260 700 091	310 946 426	352 123 402	395 049 797	445 930 341	478 362 380	526 253 907
AC	44 039 566	89 669 141	135 490 691	176 017 084	222 155 693	267 368 553	314 889 206	365 365 142	409 977 156	463 074 525	508 718 886	553 848 914
SV	- 5 985 423	3 500 793	- 20 328 852	- 1 818 675	- 846 781	408 192	9 907 893	9 477 866	11 780 781	21 014 731	13 192 117	20 724 800
CV	- 9 791 612	- 2 888 918	- 27 955 210	- 7 064 913	- 7 693 979	- 6 668 462	- 3 942 781	- 13 241 740	- 14 927 358	- 17 144 183	- 30 356 506	- 27 595 007
SPR	0,85	1,04	0,84	0,99	1,00	1,00	1,03	1,03	1,03	1,05	1,03	1,04
CPR	0,78	0,97	0,79	0,96	0,97	0,98	0,99	0,96	0,96	0,96	0,94	0,95
EAC	2 028 788 826	1 630 236 806	1 987 861 505	1 643 688 403	1 634 316 334	1 618 071 057	1 597 719 928	1 637 045 192	1 637 330 160	1 638 371 232	1 677 835 155	1 660 444 723
Var EAC vs Budget	451 074 218	52 522 197	410 146 896	65 973 794	56 601 725	40 356 448	20 005 319	59 330 583	59 615 552	60 656 623	100 120 546	82 730 114
% Variance forecast	22%	3%	21%	4%	3%	2%	1%	4%	4%	4%	6%	5%

Stoping Cost analysis as of Dec 2018

During 2018 (the first year of the three-year investigation), the stoping was ahead of plan by 5,144 m^2 (+4.1%). The total cost was overspent with R 48,319,807 million (+9.6%). The EVM calculations show a 0.95 CPR and 1.04 SPR. Although the stoping was better than planned; the cost of this overachievement was much more than what was earned. Using the CPR to calculate the Estimate at

Completion, EVM at the end of 2018 forecast if the current performance and cost trend remains, the total approved cost budget of R 1,577,714,609 may be overspent with R 82,730,114 if corrective action is not taken.

Table 27: Stoping – 2018 Schedule at Completion forecast

	Jan 18	Feb 18	Mar 18	Apr 18	May 18	Jun 18	Jul 18	Aug 18	Sep 18	Oct 18	Nov 18	Dec 18
Total PV	1577 714 609	1577 714 609	1577 714 609	1577 714 609	1577 714 609	1577 714 609	1577 714 609	1577 714 609	1577 714 609	1577 714 609	1577 714 609	1577 714 609
EAC	2 028 788 826	1630 236 806	1987 861505	1643 688 403	1634 316 334	1618 071057	1597 719 928	1637 045 192	1637 330 160	1638 371232	1677 835 155	1660 444 723
Planned Shedule	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0
Schedule at completion	42,3	34,5	42,8	36,4	36,1	35,9	34,9	35,0	34,9	34,3	35,0	34,6
Month variance	6,3	-1,5	6,8	0,4	0,1	-0,1	-1,1	-1,0	-1,1	-1,7	-1,0	-1,4
	Jan 18	Feb 18	Mar 18	Apr 18	May 18	Jun 18	Jul 18	Aug 18	Sep 18	Oct 18	Nov 18	Dec 18
Elaps Time (Since started)	1,0	2,0	3,0	4,0	5,0	6,0	7,0	8,0	9,0	10,0	11,0	12,0
Total months	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0
x (Days x SPR)	0,9	2,1	2,5	4,0	5,0	6,0	7,2	8,2	9,3	10,5	11,3	12,5
y	35,1	33,9	33,5	32,0	31,0	30,0	28,8	27,8	26,7	25,5	24,7	23,5
Total months forecast	42,3	34,5	42,8	36,4	36,1	35,9	34,9	35,0	34,9	34,3	35,0	34,6
Total Months Over/Under	6,3	- 1,5	6,8	0,4	0,1	- 0,1	- 1,1	- 1,0	- 1,1	- 1,7	- 1,0	- 1,4
% Variance forecast	15%	-4%	16%	1%	0%	0%	-3%	-3%	-3%	-5%	-3%	-4%

Stoping Schedule analysis as of Dec 2018

Using the SPR to calculate the Schedule at Completion in Table 27, EVM at the end of 2018 forecast if the current performance and cost trend remains, the total development planned to be completed within 36 months may take 1.4 months less than planned.

Table 28: Stoping – 2019 EVM Analysis + EAC

	2019											
	Jan 19	Feb 19	Mar 19	Apr 19	May 19	Jun 19	Jul 19	Aug 19	Sep 19	Oct 19	Nov 19	Dec 19
Planned m^2	132 109	142 987	154 397	163 700	173 271	184 272	195 581	206 717	217 788	228 922	240 781	252 904
Actual m^2	139 132	150 044	160 651	169 647	179 991	190 543	203 062	215 455	227 088	238 150	249 260	262 129
Planned cost	543 489 946	584 256 701	625 915 755	665 431 199	705 294 203	746 550 819	795 285 093	843 237 351	891 280 383	938 914 651	986 198 662	1 035 159 502
Actual cost	609 291 127	658 756 852	704 318 816	752 243 414	800 584 564	848 544 318	901 311 927	954 524 257	1 001 661 023	1 049 918 802	1 098 821 482	1 146 032 810
Planned rate / m^2	4 114	4 086	4 054	4 065	4 070	4 051	4 066	4 079	4 092	4 101	4 096	4 093
Actual rate / m^2	4 379	4 390	4 384	4 434	4 448	4 453	4 439	4 430	4 411	4 409	4 408	4 372
PV	543 489 946	584 256 701	625 915 755	665 431 199	705 294 203	746 550 819	795 285 093	843 237 351	891 280 383	938 914 651	986 198 662	1 035 159 502
EV	572 380 784	613 093 819	651 269 029	689 605 417	732 646 644	771 956 811	825 705 761	878 882 043	929 339 990	976 762 386	1 020 927 855	1 072 919 567
AC	609 291 127	658 756 852	704 318 816	752 243 414	800 584 564	848 544 318	901 311 927	954 524 257	1 001 661 023	1 049 918 802	1 098 821 482	1 146 032 810
SV	28 890 838	28 837 118	25 353 274	24 174 218	27 352 441	25 405 993	30 420 668	35 644 692	38 059 607	37 847 735	34 729 194	37 760 065
CV	- 36 910 343	- 45 663 033	- 53 049 787	- 62 637 997	- 67 937 920	- 76 587 506	- 75 606 166	- 75 642 214	- 72 321 033	- 73 156 416	- 77 893 626	- 73 113 243
SPR	1,05	1,05	1,04	1,04	1,04	1,03	1,04	1,04	1,04	1,04	1,04	1,04
CPR	0,94	0,93	0,92	0,92	0,92	0,91	0,92	0,92	0,93	0,93	0,93	0,94
EAC	1 679 454 550	1 695 222 292	1 706 228 970	1 721 021 027	1 724 015 216	1 734 243 091	1 722 178 846	1 713 502 826	1 700 492 012	1 695 880 447	1 698 089 336	1 685 226 705
Var EAC vs Budget	101 739 941	117 507 684	128 514 361	143 306 418	146 300 607	156 528 482	144 464 237	135 788 217	122 777 403	118 165 838	120 374 727	107 512 096
% Variance forecast	6%	7%	8%	8%	8%	9%	8%	8%	7%	7%	7%	6%

Stoping Cost analysis as of Dec 2019

During 2018 – 2019 (the first two years of the three-year investigation), as seen in Table 28, the stoping remained positive and ahead with 9,225 m^2 (+3.7%). The total cost remained overspent and was now R 110,873,308 million (+10.7%).

The EVM calculations show a 0.94 CPR and 1.04 SPR. Using the CPR to calculate the Estimate at Completion, EVM at the end of 2019 forecast if the current performance and cost trend remains, the total approved cost budget of R 1,577,714,609 can be overspent with R 107,512,096 if this trend remains without any mitigation.

Table 29: Stoping – 2019 Schedule at Completion forecast

	Jan 19	Feb 19	Mar 19	Apr 19	May 19	Jun 19	Jul 19	Aug 19	Sep 19	Oct 19	Nov 19	Dec 19
Total PV	1577 714 609	1577 714 609	1577 714 609	1577 714 609	1577 714 609	1577 714 609	1577 714 609	1577 714 609	1577 714 609	1577 714 609	1577 714 609	1577 714 609
EAC	1679 454 550	1695 222 292	1706 228 970	1721021027	1724 015 216	1734 243 091	1722 178 846	1713 502 826	1700 492 012	1695 880 447	1698 089 336	1685 226 705
Planned Shedule	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0
Schedule at completion	34,2	34,3	34,6	34,7	34,7	34,8	34,7	34,5	34,5	34,6	34,8	34,7
Month variance	-1,8	-1,7	-1,4	-1,3	-1,3	-1,2	-1,3	-1,5	-1,5	-1,4	-1,2	-1,3

	Jan 19	Feb 19	Mar 19	Apr 19	May 19	Jun 19	Jul 19	Aug 19	Sep 19	Oct 19	Nov 19	Dec 19
Elaps Time (Since started)	13,0	14,0	15,0	16,0	17,0	18,0	19,0	20,0	21,0	22,0	23,0	24,0
Total months	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0
x (Days x SPR)	13,7	14,7	15,6	16,6	17,7	18,6	19,7	20,8	21,9	22,9	23,8	24,9
y	22,3	21,3	20,4	19,4	18,3	17,4	16,3	15,2	14,1	13,1	12,2	11,1
Total months forecast	34,2	34,3	34,6	34,7	34,7	34,8	34,7	34,5	34,5	34,6	34,8	34,7
Total Months Over/Under	- 1,8	- 1,7	- 1,4	- 1,3	- 1,3	- 1,2	- 1,3	- 1,5	- 1,5	- 1,4	- 1,2	- 1,3
% Variance forecast	-5%	-5%	-4%	-4%	-4%	-3%	-4%	-4%	-4%	-4%	-4%	-4%

Stoping Schedule analysis as of Dec 2019

The calculated Schedule at Completion shown in Table 29 at the end of the 2018 – 2019 (the first two years of the three-year investigation) period shows that if the current performance and cost trend remains, the total development planned to be completed within 36 months may take 1.3 months less to achieve the total planned stoping.

Table 30: Stoping – 2020 EVM Analysis + EAC

	2020											
	Jan 20	Feb 20	Mar 20	Apr 20	May 20	Jun 20	Jul 20	Aug 20	Sep 20	Oct 20	Nov 20	Dec 20
Planned m^2	260 148	271 081	283 167	289 244	295 665	302 233	309 210	321 123	333 259	345 755	358 880	371 841
Actual m^2	268 591	279 819	289 658	293 807	301 092	308 461	315 786	325 810	340 130	353 292	364 278	377 285
Planned cost	1 080 971 186	1 129 222 207	1 178 971 285	1 207 851 274	1 238 359 734	1 269 572 051	1 302 728 588	1 357 348 705	1 411 158 018	1 466 364 226	1 522 490 237	1 577 714 609
Actual cost	1 190 306 641	1 237 339 398	1 281 836 952	1 308 403 517	1 345 670 307	1 383 313 051	1 430 398 537	1 486 206 570	1 555 359 806	1 623 165 563	1 687 784 476	1 753 240 938
Planned rate / m^2	4 155	4 166	4 164	4 176	4 188	4 201	4 213	4 227	4 234	4 241	4 242	4 243
Actual rate / m^2	4 432	4 422	4 425	4 453	4 469	4 485	4 530	4 562	4 573	4 594	4 633	4 647
PV	1 080 971 186	1 129 222 207	1 178 971 285	1 207 851 274	1 238 359 734	1 269 572 051	1 302 728 588	1 357 348 705	1 411 158 018	1 466 364 226	1 522 490 237	1 577 714 609
EV	1 116 053 456	1 165 622 164	1 205 996 666	1 226 904 075	1 261 092 130	1 295 734 703	1 330 433 370	1 377 161 701	1 440 254 592	1 498 328 545	1 545 391 880	1 600 815 394
AC	1 190 306 641	1 237 339 398	1 281 836 952	1 308 403 517	1 345 670 307	1 383 313 051	1 430 398 537	1 486 206 570	1 555 359 806	1 623 165 563	1 687 784 476	1 753 240 938
SV	35 082 271	36 399 957	27 025 382	19 052 801	22 732 396	26 162 652	27 704 782	19 812 996	29 096 574	31 964 319	22 901 643	23 100 785
CV	- 74 253 185	- 71 717 233	- 75 840 286	- 81 499 441	- 84 578 176	- 87 578 347	- 99 965 167	- 109 044 869	- 115 105 214	- 124 837 018	- 142 392 596	- 152 425 544
SPR	1,03	1,03	1,02	1,02	1,02	1,02	1,02	1,01	1,02	1,02	1,02	1,01
CPR	0,94	0,94	0,94	0,94	0,94	0,94	0,93	0,93	0,93	0,92	0,92	0,91
EAC	1 682 682 999	1 674 786 653	1 676 930 743	1 682 517 308	1 683 527 833	1 684 351 899	1 696 259 819	1 702 639 432	1 703 805 634	1 709 165 877	1 723 085 425	1 727 940 555
Var EAC vs Budget	104 968 390	97 072 045	99 216 135	104 802 700	105 813 224	106 637 291	118 545 210	124 924 823	126 091 025	131 451 268	145 370 816	150 225 946
% Variance forecast	6%	6%	6%	6%	6%	6%	7%	7%	7%	8%	8%	9%

Stoping Cost analysis as of Dec 2020

During 2018 – 2020 (the total planned program), the stoping ended with 5,444 m^2 (+1.6%) more production than initially planned, as seen in Table 30. The total cost was now overspent with R 175,526,329 (+11.1%).

The EVM calculations show a CPR of 0.91 and an SPR of 1.01.

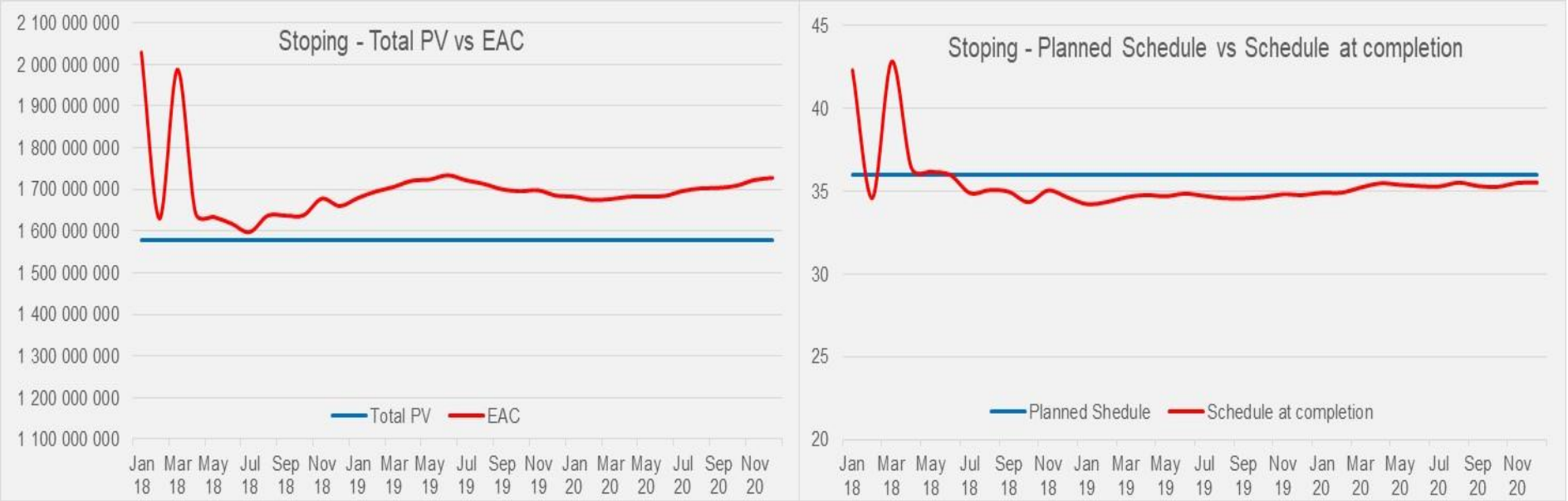
The final summary shows an actual cost of over R 1,753,240,938 and stoping realised an Earned Value of R 1,600,815,398. Although the work done was better than planned (EV vs PV), a larger budget overrun occurred over this period.

Table 31: Stoping – 2020 Schedule at Completion forecast

	Jan 20	Feb 20	Mar 20	Apr 20	May 20	Jun 20	Jul 20	Aug 20	Sep 20	Oct 20	Nov 20	Dec 20
Total PV	1577 714 609	1577 714 609	1577 714 609	1577 714 609	1577 714 609	1577 714 609	1577 714 609	1577 714 609	1577 714 609	1577 714 609	1577 714 609	1577 714 609
EAC	1682 682 999	1674 786 653	1676 930 743	1682 517 308	1683 527 833	1684 351 899	1696 259 819	1702 639 432	1703 805 634	1709 165 877	1723 085 425	1727 940 555
Planned Shedule	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0
Schedule at completion	34,9	34,9	35,2	35,4	35,4	35,3	35,3	35,5	35,3	35,2	35,5	35,5
Month variance	-1,1	-1,1	-0,8	-0,6	-0,6	-0,7	-0,7	-0,5	-0,7	-0,8	-0,5	-0,5
	Jan 20	Feb 20	Mar 20	Apr 20	May 20	Jun 20	Jul 20	Aug 20	Sep 20	Oct 20	Nov 20	Dec 20
Elaps Time (Since started)	25,0	26,0	27,0	28,0	29,0	30,0	31,0	32,0	33,0	34,0	35,0	36,0
Total months	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0	36,0
x (Days x SPR)	25,8	26,8	27,6	28,4	29,5	30,6	31,7	32,5	33,7	34,7	35,5	36,5
y	10,2	9,2	8,4	7,6	6,5	5,4	4,3	3,5	2,3	1,3	0,5	- 0,5
Total months forecast	34,9	34,9	35,2	35,4	35,4	35,3	35,3	35,5	35,3	35,2	35,5	35,5
Total Months Over/Under	- 1,1	- 1,1	- 0,8	- 0,6	- 0,6	- 0,7	- 0,7	- 0,5	- 0,7	- 0,8	- 0,5	- 0,5
% Variance forecast	-3%	-3%	-2%	-2%	-2%	-2%	-2%	-1%	-2%	-2%	-2%	-1%

Stoping Schedule analysis as of Dec 2020

With the over-performance of 5,444 m^2 (+1.6%) stoping over the 36 months, SPR was used to calculate the Schedule at Completion in Table 31. The EVM calculation at the end of 2018 – 2020 forecast that the scheduled amount of stoping was achieved with 0.5 months less than initially planned due to the better-than-planned achievements.



Graph 19: Stoping PV vs EAC & PS vs Schedule at Completion

Graph 19 show the total EAC vs the original planned total budget as it progressed over the 36 months. The Schedule at Completion also reflects the forecast months the period may extend to if the SPR did not increase. It is clear that stoping costs have had severe challenges since August 2018 and have never recovered.

Graph 20: Stoping Earned Value Analysis

As seen in Graph 20, the PV was not achieved over this period. The final EVM analysis was as follows:

PV: R 1,577,714,609

EV: R 1,600,815,394

AC: R 1,753,240,938

SV: R 23,100,785 Due to good performance, this cost should have been saved.

CV:- R 152,425,544 Over-expenditure over the 36 month duration.

4.3 SUMMARY OF OCD AND STOPING EVM ANALYSIS

4.3.1 OCD – Summary of EAC and Schedule at Completion

Table 32: Summary of OCD EAC and SAC

	Ongoing-Capital-Development Analysis					
	EVM Cost prediction			EVM Schedule prediction		
	Total budget	Estimate at Completion	Var EAC vs Budget	Total period	Schedule at Completion	Var SAC vs period
Jan 18	1 097 917 233	2 019 688 457	921 771 224	36	72,4	36,4
Feb 18	1 097 917 233	1 542 571 844	444 654 611	36	57,1	21,1
Mar 18	1 097 917 233	1 687 535 044	589 617 811	36	66,9	30,9
Apr 18	1 097 917 233	1 358 635 012	260 717 780	36	56,4	20,4
May 18	1 097 917 233	1 311 627 727	213 710 494	36	55,6	19,6
Jun 18	1 097 917 233	1 262 563 508	164 646 275	36	55,6	19,6
Jul 18	1 097 917 233	1 197 543 240	99 626 007	36	51,4	15,4
Aug 18	1 097 917 233	1 201 116 634	103 199 401	36	49,7	13,7
Sep 18	1 097 917 233	1 200 445 038	102 527 805	36	49,1	13,1
Oct 18	1 097 917 233	1 192 116 814	94 199 581	36	47,5	11,5
Nov 18	1 097 917 233	1 205 038 489	107 121 256	36	47,7	11,7
Dec 18	1 097 917 233	1 218 226 823	120 309 590	36	47,2	11,2
Jan 19	1 097 917 233	1 235 361 484	137 444 251	36	47,6	11,6
Feb 19	1 097 917 233	1 215 660 433	117 743 201	36	46,4	10,4
Mar 19	1 097 917 233	1 193 232 410	95 315 177	36	45,0	9,0
Apr 19	1 097 917 233	1 184 020 500	86 103 267	36	44,2	8,2
May 19	1 097 917 233	1 169 528 771	71 611 538	36	43,2	7,2
Jun 19	1 097 917 233	1 170 492 885	72 575 652	36	42,7	6,7
Jul 19	1 097 917 233	1 134 805 081	36 887 848	36	41,1	5,1
Aug 19	1 097 917 233	1 129 044 557	31 127 324	36	40,7	4,7
Sep 19	1 097 917 233	1 124 696 639	26 779 407	36	40,4	4,4
Oct 19	1 097 917 233	1 115 717 805	17 800 572	36	40,0	4,0
Nov 19	1 097 917 233	1 105 616 062	7 698 829	36	39,8	3,8
Dec 19	1 097 917 233	1 092 105 964	- 5 811 269	36	39,4	3,4
Jan 20	1 097 917 233	1 093 377 536	- 4 539 697	36	39,6	3,6
Feb 20	1 097 917 233	1 087 208 111	- 10 709 122	36	39,4	3,4
Mar 20	1 097 917 233	1 092 112 830	- 5 804 403	36	39,6	3,6
Apr 20	1 097 917 233	1 078 736 768	- 19 180 465	36	39,6	3,6
May 20	1 097 917 233	1 078 741 657	- 19 175 576	36	39,6	3,6
Jun 20	1 097 917 233	1 073 919 612	- 23 997 621	36	39,8	3,8
Jul 20	1 097 917 233	1 066 780 010	- 31 137 223	36	39,5	3,5
Aug 20	1 097 917 233	1 065 643 400	- 32 273 833	36	39,7	3,7
Sep 20	1 097 917 233	1 063 898 673	- 34 018 560	36	39,7	3,7
Oct 20	1 097 917 233	1 061 558 949	- 36 358 284	36	39,5	3,5
Nov 20	1 097 917 233	1 058 593 804	- 39 323 429	36	39,4	3,4
Dec 20	1 097 917 233	1 060 916 290	- 37 000 943	36	39,3	3,3

4.3.2 Stoping - Summary of EAC and Schedule at Completion

Table 33: Summary of OCD EAC and SAC

	Stoping Analysis					
	EVM Cost prediction			EVM Schedule prediction		
	Total budget	Estimate at Completion	Var EAC vs Budget	Total period	Schedule at Completion	Var SAC vs period
Jan 18	1 577 714 609	2 028 788 826	451 074 218	36	42,3	6,3
Feb 18	1 577 714 609	1 630 236 806	52 522 197	36	34,5	-1,5
Mar 18	1 577 714 609	1 987 861 505	410 146 896	36	42,8	6,8
Apr 18	1 577 714 609	1 643 688 403	65 973 794	36	36,4	0,4
May 18	1 577 714 609	1 634 316 334	56 601 725	36	36,1	0,1
Jun 18	1 577 714 609	1 618 071 057	40 356 448	36	35,9	-0,1
Jul 18	1 577 714 609	1 597 719 928	20 005 319	36	34,9	-1,1
Aug 18	1 577 714 609	1 637 045 192	59 330 583	36	35,0	-1,0
Sep 18	1 577 714 609	1 637 330 160	59 615 552	36	34,9	-1,1
Oct 18	1 577 714 609	1 638 371 232	60 656 623	36	34,3	-1,7
Nov 18	1 577 714 609	1 677 835 155	100 120 546	36	35,0	-1,0
Dec 18	1 577 714 609	1 660 444 723	82 730 114	36	34,6	-1,4
Jan 19	1 577 714 609	1 679 454 550	101 739 941	36	34,2	-1,8
Feb 19	1 577 714 609	1 695 222 292	117 507 684	36	34,3	-1,7
Mar 19	1 577 714 609	1 706 228 970	128 514 361	36	34,6	-1,4
Apr 19	1 577 714 609	1 721 021 027	143 306 418	36	34,7	-1,3
May 19	1 577 714 609	1 724 015 216	146 300 607	36	34,7	-1,3
Jun 19	1 577 714 609	1 734 243 091	156 528 482	36	34,8	-1,2
Jul 19	1 577 714 609	1 722 178 846	144 464 237	36	34,7	-1,3
Aug 19	1 577 714 609	1 713 502 826	135 788 217	36	34,5	-1,5
Sep 19	1 577 714 609	1 700 492 012	122 777 403	36	34,5	-1,5
Oct 19	1 577 714 609	1 695 880 447	118 165 838	36	34,6	-1,4
Nov 19	1 577 714 609	1 698 089 336	120 374 727	36	34,8	-1,2
Dec 19	1 577 714 609	1 685 226 705	107 512 096	36	34,7	-1,3
Jan 20	1 577 714 609	1 682 682 999	104 968 390	36	34,9	-1,1
Feb 20	1 577 714 609	1 674 786 653	97 072 045	36	34,9	-1,1
Mar 20	1 577 714 609	1 676 930 743	99 216 135	36	35,2	-0,8
Apr 20	1 577 714 609	1 682 517 308	104 802 700	36	35,4	-0,6
May 20	1 577 714 609	1 683 527 833	105 813 224	36	35,4	-0,6
Jun 20	1 577 714 609	1 684 351 899	106 637 291	36	35,3	-0,7
Jul 20	1 577 714 609	1 696 259 819	118 545 210	36	35,3	-0,7
Aug 20	1 577 714 609	1 702 639 432	124 924 823	36	35,5	-0,5
Sep 20	1 577 714 609	1 703 805 634	126 091 025	36	35,3	-0,7
Oct 20	1 577 714 609	1 709 165 877	131 451 268	36	35,2	-0,8
Nov 20	1 577 714 609	1 723 085 425	145 370 816	36	35,5	-0,5
Dec 20	1 577 714 609	1 727 940 555	150 225 946	36	35,5	-0,5

4.4 POSSIBLE FUTURE EXTENSION OF RESEARCH

While conducting this study, the following areas of concern became evident:

- Face advance. The face advance is the stoping panel that is mined to extract the reef. As noticed in Table 33, the average face advance achievement was 6.7 m per month. The face advance two decades ago was almost three times of this performance. A study determining the factors that caused this lower plan and achievements may be highly beneficial to challenge these factors.

Table 34: Face advance average per year vs actual (A-Mine)

		UOM	2016	2017	2018	2019	2020	5Yr average
Face advance	Average Plan / month	m	6,6	6,6	5,6	5,8	7,3	**6,4**
	Average Actual / month	m	6,0	6,3	7,1	6,8	7,2	**6,7**
	Variance	m	- 0,6	- 0,2	1,5	1,0	- 0,1	**0,3**

Graph 21: Face advance average per year vs actual (A-Mine)

- Mine Call Factor (MCF). The MCF is the percentage of gold that is lost due to various reasons. The geologist determines the gold grade per ton utilising history and exploration drilling programs. Once mining is done in these areas, it is found that the gold is not as determined. This factor will implicate the amount of gold not recovered.

Table 35: MCF 5 year average plans vs actual (A-Mine)

		UOM	2016	2017	2018	2019	2020	5 Yr average
MCF	Mining average plan	%	74,1%	73,6%	74,6%	74,6%	68,8%	**73,1%**
	Mining average actual	%	76,5%	73,7%	77,1%	64,6%	64,9%	**71,4%**
	Variance	%	2,4%	0,1%	2,5%	-10,0%	-3,9%	**-1,8%**

An average of -1.8 % less on the MCF than planned may not look like a lot. But when looking at the number of mined tonnes, this small percentage adds up to millions lost in revenue.

Graph 22: MCF 5 year average plans vs actual (A-Mine)

The negative impact can be researched if the study is extended, and alternative management solutions could be proposed.

4.5 LESSONS LEARNED

A general assumption made is that a small percentage do not matter. In the case of the stoping analysis, the costs are overspent with only 11.1%. This percentage does not sound like much, but in this case, it was R 175,526,329. When percentages are discussed, the context in which they are mentioned and their impact need to be understood.

4.6 CONCLUSION

This study was based only on the summarised OCD and stoping parameters over three years. A better value will be created if the survey can be done in detail to demonstrate

the problem's key value destroyers and value contributors. Areas of concern are easily identifiable when looking at the analyses. Still, when it can be done in more detail, the areas per responsible Manager, Mine Overseer or Shift Overseer could be analysed. An underperforming supervisor's progress is now hidden within the better performance of their colleagues.

5 CHAPTER 5 – CONCLUSION AND RECOMMENDATION

5.1 INTRODUCTION

The objectives for this study were:

- to demonstrate the effectiveness of using EVM on operational cost activities;
- create awareness on how EVM can assist in tracking the program better and saving millions of Rands within the operational cost areas;
- to demonstrate how production can be effectively managed (cost vs progress) by using more extended durations; and
- to show the simplicity in using a dashboard (CPR & SPR) by offering the ease of reporting and visibility of variance results.

The benefit of this contribution has been identifying what improvement using EVM on working costs can add to the overall strategy of making a mine more successful and sustainable.

The benefits for the mine, which were demonstrated through this research by using EVM, would include a(n):

- decrease its operating cost expenditure (increase efficiencies);
- increase its production rates due to better focus on the bigger picture; and
- increase profitability.

This study's findings demonstrated the benefits of using EVM, which can give the mine a competitive advantage in the mining industry. Earned Value Management must still find its place in the mining operation cost discipline. Using EVM will make a great mine an even better one.

5.2 FINDINGS FROM DATA

This study was only focused on the OCD, stoping planned, and actual performances. The raw data received gave the following incremental values:

Ongoing-Capital-Development

- Planned metres – 26,003 metres
- Planned cost – R 1,097,917,233

- Actual metres achieved – 23,833 metres
- Actual expenditure achieved – R 972,389,012

From the initial data, it is clear that the OCD underperformed with 2,170 metres over the three years, and the total cost was underspent with R 125,528,221. The data did not show if the value of money was achieved or how far the OCD have fallen behind. The early indication was the production was 9.1% below target, and the cost was 12.9% underspent. This cost was a positive indication.

Stoping

- Planned m^2 – 371,841 m^2
- Planned cost – R 1,577,714,609
- Actual m^2 achieved – 377,285 m^2
- Actual expenditure achieved – R 1,753,240,938

From the original data, over the three years, the stoping over-performed with 5,444 m^2 and the total cost was overspent with R 175,526,329. These achievements do not indicate value for money or how far the stoping has overachieved the plan. Doing more work justified more costs but is the additional cost in line with the additional stoping achieved? The early indication showed that the production had achieved 1.4 % more stoping, but the cost was overspent by 11.1%. An early challenge could be noticed with the large discrepancy between the work achieved and the cost percentage overrun.

5.3 FINDINGS FROM THE OBSERVED STUDY

An Excel database with the abovementioned data was compiled to allow for cumulative values and EVM calculations. This calculation could determine the PV, EV, AC, CV, SV, CPR and SPR at any given month over the three-year window. Using the CPR and SPR, a forecast of the likely over-or under-expenditure could be determined. With the SPR, a forest on the schedule deviation could be calculated.

The final EVM analysis for OCD was as follows:

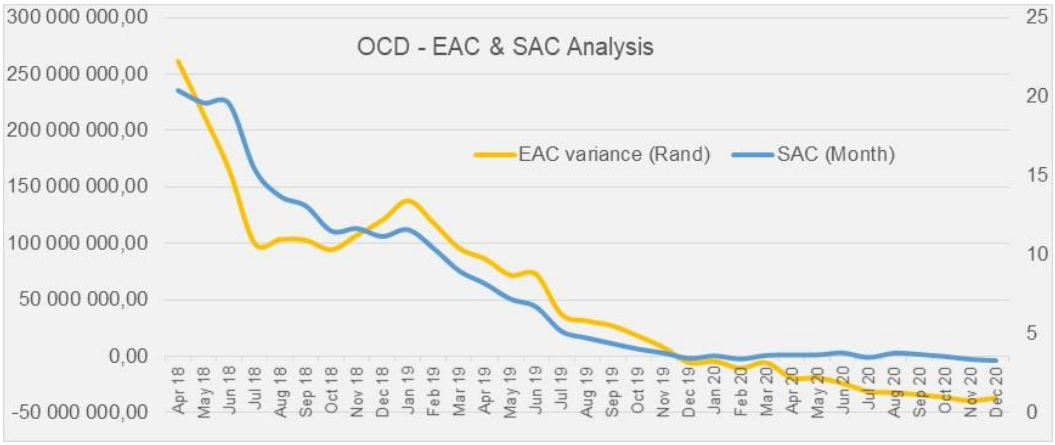
PV: R 1,907,917,233

EV: R 1,006,302,402

AC: R 972,389,012

SV:- R 91,614,791

CV: R 33,913,430



Graph 23: OCD EAC & SAC Analysis

This study determined and demonstrated with EVM the forecasting ability of the cost and schedule outcome by using the CPR and SPR. The progress on areas can be seen in Graph 23 and Graph 24 on how the changes during the duration took place. This information will be compelling if it can be available for proactive management to take place.

The final EVM analysis for the stoping was as follows:

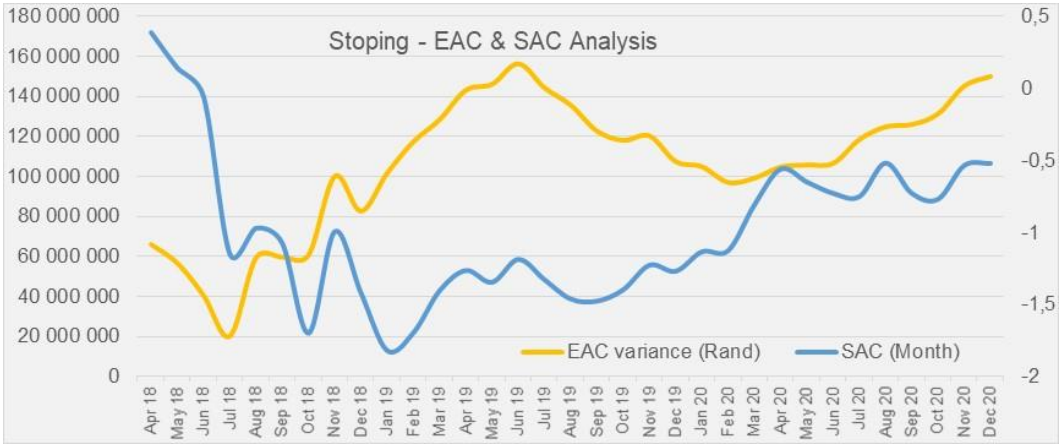
PV: R 1,577,714,609

EV: R 1,600,815,394

AC: R 1,753,240,938

SV: R 23,100,785

CV:- R 152,425,544



Graph 24: Stoping EAC & SAC Analysis

5.4 PROPOSED STRATEGY

It is proposed that the mine seek its poorest-performing OCD and stoping section and do an EVM trial on them. Budgets for the production and cost targets to be achieved over a minimum of a two-year window should be compiled. The benefits will be seen within the first six months, and the rest of the OCD and stoping production areas can be adapted in the new budget cycle to comply with the EVM methodology. If the end-users (Mine-overseers) can see the bigger picture better and the consequences of their performance during the early stages, they will engage in better pro-active interventions to ensure the end target will be met. Early detection of variance will ensure that early corrective action is taken, hence providing the program and cost not to deviate and cause unnecessary loss of production and loss of revenue.

5.5 LIMITATIONS TO THE STUDY

This study was done only using the summarised available information of the OCD and stoping areas over three years. The research intends to determine and demonstrate if and how EVM can add value to the abovementioned areas of concern. Although the study has reached its goal, a lower level of detail would have highlighted the areas that cause the organisation not to create ultimate value.

5.6 FUTURE RESEARCH STUDIES

The future value-adding research that should be done is:

- South African remaining gold – With the highest recorded annual gold production of 619.2 tonnes during 1993 and a mere 90 tonnes being produced during 2020, the question must be asked: Why? Has South Africa reached its record productions levels, or have our mines become inefficient producers of gold?
- Face advance – The face advance is the distance a gold-bearing stope is mined and measured in metres.
    - Benchmarking against production levels of the period between 1980 and 2000 would answer if our gold has depleted,
    - or if the labour force has lost its production and efficiency ability.
- Looking at what the effect of the current salary structures is on productivity. High salaries with low incentives (bonuses) if targets are met vs low salaries with high incentives (bonuses) if production targets are achieved.

5.7 CHAPTER SUMMARY

This study has proven that millions of Rands can be saved by implementing EVM on the operational cost areas of the mine. Furthermore, by using this tool to determine the outcome of the schedule based on its current performance, the potential loss can be calculated or mitigated.

The commitment of all mine employees is evident, but to this day, any additional tool that can assist in better management must be embraced. The main benefit of implementing EVM is that the scope, time, and money are entirely integrated, and if one of these areas moves from the pre-determined line, it becomes apparent.

6 REFERENCES

AACEI, 2021. *Cost Engineering.* [Online]
Available at: https://web.aacei.org/about-aace/what-is-cost-engineering
[Accessed 11 September 2021].

Accram, A., 2021. *Mining sector contributes R400 billion to GDP in 2020: Minerals Council.* [Online]
Available at: https://www.sabcnews.com/sabcnews/mining-sector-contributes-r400-billion-to-gdp-in-2020-minerals-council/
[Accessed 11 September 2021].

Akhouri, A., 2020. *Cross-sectional study Vs. Longitudinal study (research).* [Online]
Available at: https://www.amritaakhouri.com/single-post/2018/02/08/cross-sectional-study-vs-longitudinal-study-research
[Accessed 27 September 2021].

Anbari, F. T., 2011. *Advances in earned schedule and earned value management.* [Online]
Available at: https://www.pmi.org/learning/library/advances-earned-schedule-value-management-6217
[Accessed 22 November 2021].

Artifacts, M., 2021. *South African Mines.* [Online]
Available at: http://www.miningartifacts.org/South-African-Mines.html
[Accessed 23 September 2021].

Buthelezi, L., 2021. *Mantashe outlines plan to get mining to contribute at least 12% of SA's GDP.* [Online]
Available at: https://www.news24.com/fin24/economy/south-africa/mantashe-outlines-plan-to-get-mining-to-contribute-at-least-12-of-sas-gdp-20210527
[Accessed 15 September 2021].

CEIC, 2021. *South Africa Gold Production.* [Online]
Available at: https://www.ceicdata.com/en/indicator/south-africa/gold-production
[Accessed 17 August 2021].

Club, O. C., 2021. *One Rand 2020, Coin from South Africa - detailed information.* [Online]
Available at: https://onlinecoin.club/Coins/Country/South_Africa/One_Rand_2020/
[Accessed 02 September 2021].

Consulting, T. S., 2021. *THE HISTORY OF EARNED VALUE MANAGEMENT.* [Online]
Available at: https://tensix.com/the-history-of-earned-value-management
[Accessed 19 September 2021].

Cornish, L., 2015. *SEFATENG CHROME MINE.* [Online]
Available at: https://www.miningreview.com/tag/sefateng-chrome-mine/
[Accessed 07 October 2021].

Dreamstime, 2021. *Conveyor mining stock photos.* [Online]
Available at: https://www.dreamstime.com/royalty-free-stock-photo-conveyor-belt-crusher-image19796625#_
[Accessed 11 October 2021].

Eby, K., 2021. *The Triple Constraint: The Project Management Triangle of Scope, Time, and Cost.* [Online]
Available at: https://www.smartsheet.com/triple-constraint-triangle-theory
[Accessed 11 September 2021].

Economics, T., 2021. *Gold.* [Online]
Available at: https://tradingeconomics.com/commodity/gold
[Accessed 17 October 2021].
Encyclopaedia, T. E. o., 2021. *stoping.* [Online]
Available at: https://www.britannica.com/technology/stoping
[Accessed 14 October 2021].
Fostel, C., 2011. *The value of earned value management.* [Online]
Available at: https://www.pmi.org/learning/library/earned-value-management-systems-analysis-8026
[Accessed 14 September 2021].
Garside, 2020. *Revenue distribution of mineral mining in South Africa in 2020, by commodity.* [Online]
Available at: https://www.statista.com/statistics/1014905/south-africa-mineral-commodity-revenue/
[Accessed 29 August 2021].
Gold(A), H., 2021. *Mineral Resources and Mineral Reserves.* [Online]
Available at: https://www.har.co.za/21/
[Accessed 14 October 2021].
Gold(B), H., 2021. *Mineral Resources and Mineral Reserves.* [Online]
Available at: https://www.har.co.za/21/
[Accessed 19 October 2021].
Goldfields-Southdeep, 2021. *Overview.* [Online]
Available at: https://www.goldfields-southdeep.co.za/about-us/about-south-deep/overview
[Accessed 17 October 2021].
Gold, H., 2021. *Mponeng.* [Online]
Available at: https://www.harmony.co.za/business/sa/mponeng
[Accessed 11 September 2021].
GoldHub, 2021. *Gold mine production.* [Online]
Available at: https://www.gold.org/goldhub/data/historical-mine-production
[Accessed 15 September 2021].
Guide, P., 2021. *PMBOK® Guide.* [Online]
Available at: https://www.pmi.org/pmbok-guide-standards/foundational/PMBOK
[Accessed 18 September 2021].
Guide, T. S. A., 2021. *The Great Trek.* [Online]
Available at: https://www.thesouthafricaguide.com/famous-south-africans-and-history/south-african-history-history-of-south-africa-the-great-trek/
[Accessed 09 September 2021].
Harper, J., 2020. *How much gold is there left to mine in the world?.* [Online]
Available at: https://www.bbc.com/news/business-54230737
[Accessed 14 September 2021].
History, S. A., 2016. *Discovery of the Gold in 1884.* [Online]
Available at: https://www.sahistory.org.za/article/discovery-gold-1884
[Accessed 17 September 2021].
International, A., 2017. *What is Earned Value Management and Why is it Important?.* [Online]
Available at: https://apmg-international.com/article/what-earned-value-management-and-why-it-important
[Accessed 27 September 2021].

IQ, A. M., 2019. *Gold Mining in South Africa.* [Online]
Available at: https://www.projectsiq.co.za/gold-mining-in-south-africa.htm
[Accessed 04 September 2021].
Johnson, D., 2021. *What is Data Analysis?.* [Online]
Available at: https://www.guru99.com/what-is-data-analysis.html#:~:text=Data%20analysis%20is%20defined%20as,based%20upon%20the%20data%20analysis.
[Accessed 05 October 2021].
Lanel, A., 2015. *Tough choices facing the South African mining industry.* [Online]
Available at: http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S2225-62532015000600006
[Accessed 7 September 2021].
M.Garside, 2021. *Number of people employed by South Africa's mining industry in 2020 by commodity.* [Online]
Available at: https://www.statista.com/statistics/241420/south-african-mining-key-facts/
[Accessed 12 September 2021].
Martin, J., 2021. *Tailings Facility Design.* [Online]
Available at: https://www.srk.com/en/projects/karar-iron-ore-mine-tailings
[Accessed 11 October 2021].
Mining, W. W., 2021. *WITWATERSRAND BASIN PROJECT.* [Online]
Available at: https://westwitsmining.com/witwatersrand-basin-project/
[Accessed 27 August 2021].
OANDA, 2020. *South African Rand.* [Online]
Available at: https://www1.oanda.com/currency/iso-currency-codes/ZAR
[Accessed 11 September 2021].
Pinkasovitch, A., 2021. *An Introduction to Capital Budgeting.* [Online]
Available at: https://www.investopedia.com/articles/financial-theory/11/corporate-project-valuation-methods.asp
[Accessed 08 September 2021].
Point, J. T., 2021. *Data Mining Implementation Process.* [Online]
Available at: https://www.javatpoint.com/implementation-process-of-data-mining
[Accessed 01 October 2021].
Reader, S., 2020. *Earned Value Management Formulas and Calculations.* [Online]
Available at: https://www.schedulereader.com/blog/earned-value-management-formulas-and-calculations
[Accessed 28 September 2021].
Roseke, B., 2018. *Estimate at Completion (Earned Value Analysis).* [Online]
Available at: https://www.projectengineer.net/estimate-at-completion-earned-value-analysis/
[Accessed 14 September 2021].
Services, M. P., 2020. *The Origins and History of Earned Value Management.* [Online]
Available at: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/viewer.html?pdfurl=https%3A%2F%2Fmosaicprojects.com.au%2FPDF_Papers%2FP207_EVM_History.pdf&clen=473503&chunk=true
[Accessed 15 September 2021].
StatsSA, 2017. *Mining: A brief history.* [Online]
Available at: http://www.statssa.gov.za/wp-content/uploads/2017/04/Mining_pic2.png
[Accessed 17 August 2021].

Stillwater, S., 2021. *Sibanye-Stillwater Mineral Resources and Mineral Reserves 2020.* [Online]
Available at: https://www.sibanyestillwater.com/business/southern-africa/gold-operations/beatrix/
[Accessed 14 October 2021].
Thompson, K., 2017. *The Steps of Quantitative Research.* [Online]
Available at: https://revisesociology.com/2017/11/26/the-steps-of-quantitative-research/
[Accessed 27 September 2021].
tools, A., 2021. *What is flex budgeting.* [Online]
Available at: https://www.accountingtools.com/articles/how-does-flex-budgeting-work.html
[Accessed 19 October 2021].
Viewpoint, 2021. *MINE FEATURES.* [Online]
Available at: http://viewpointmining.com/index.php
[Accessed 03 October 2021].
Wikipedia, 2021. *List of countries by gold production.* [Online]
Available at: https://en.wikipedia.org/wiki/List_of_countries_by_gold_production
[Accessed 15 September 2021].
Wondershare, 2021. *Work Breakdown Structure (WBS) for Dummies: The Ultimate Guide.* [Online]
Available at: https://www.edrawmax.com/wbs/
[Accessed 19 September 2021].

7 APPENDICES

7.1 APPENDIX A – SOLEMN DECLARATION AND PERMISSION TO SUBMIT

NWU®

NORTH-WEST UNIVERSITY
NOORDWES-UNIVERSITEIT
YUNIBESITI YA BOKONE-BOPHIRIMA

NWU Higher Degrees Administration

SOLEMN DECLARATION AND PERMISSION TO SUBMIT

1. Solemn declaration by student

I, **Stanley Taylor**

declare herewith that the thesis/dissertation/mini-dissertation/article entitled (**exactly as registered/approved title**),

Analysing operational cost performance in selected gold mines in South Africa

which I herewith submit to the North-West University is in compliance/partial compliance with the requirements set for the degree:

Masters of Business Administration

is my own work, has been text-edited in accordance with the requirements and has not already been submitted to any other university.

LATE SUBMISSION: If a thesis/dissertation/mini-dissertation/article of a student is submitted after the deadline for submission, the period available for examination is limited. No guarantee can therefore be given that (should the examiner reports be positive) the degree will be conferred at the next applicable graduation ceremony. It may also imply that the student would have to re-register for the following academic year.

Ethics number: NWU-00944-21-A4

ORCID: 0000-0002-0628-4628

Signature of Student: Stan Taylor — Digitally signed by Stan Taylor Date: 2021.12.03 12:55:13 +02'00'

University Number: 26316919

Signed on this 03 day of December of 20 21

2. Permission to submit and solemn declaration by supervisor/promotor

The undersigned declares that the thesis/dissertation/mini-dissertation/article:

- ☑ complies with the A-rules and the technical requirements provided for in the Manual for Master's and Doctoral studies and in faculty rules;
- ☑ has been checked by me for plagiarism (by making use of Turnitin software for example) and a satisfactory report has been obtained;
- ☑ and that the work was language edited before submission for examination.

Faculty specific requirements as per A-rules: 1.3.2, 4.3.3, 4.2.4, 4.10.4, 5.3.3

- ☐ complies with regards to faculty rules on submission or acceptance by an accredited scientific journal;
- ☐ complies with regards to faculty rules on peer reviewed conference proceedings;
- ☑ the student is hereby granted permission to submit his/her article/mini-dissertation/ dissertation/thesis for examination.

Signatures of supervisor(s) and Promotor(s): (only compulsory in cases where there are co- or assistant- supervisor(s)/promotors)

Johan Jordaan — Digitally signed by Johan Jordaan Date: 2021.12.06 10:00:22 +02'00'

Co-Supervisor/Co-Promotor

Assistant -Supervisor
Assistant-Promotor

Original details: Marietjie Ackermann(10512187) BSORHDA-HSM-DA Technical Panel 19.8 SOLEMN DECLARATION AND PERMISSION TO SUBMIT.docm 1 Oct 2019

File reference: 7.1.11.3.2/3

7.2 APPENDIX B – ETHICS APPLICATION FORM

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT

Private Bag X6001, Potchefstroom
South Africa 2520

Tel: 018 299-1111/2222
Web: http://www.nwu.ac.za

Economic and Management Sciences Research
Ethics Committee (EMS-REC)

30 August 2021

Dr J Jordaan
Per e-mail
Dear Dr Jordaan,

EMS-REC FEEDBACK: 27082021
Student: Taylor, S (26316919)(NWU-00944-21-A4)
Study leader: Dr J Jordaan - MBA

Your ethics application on, ***Analysing operational cost performance in gold mines by using earned value management,*** which served on the EMSREC meeting of 27 August 2021, refers.

Outcome:

Approved as a minimal risk study. A number **NWU-00944-21-A4** is given for one year of ethics clearance.

Please note that the ethics approval of this application is subject to the Covid-19 protocols.

Kind regards,

Mark Rathbone

Prof Mark Rathbone
Chairperson: Economic and Management Sciences Research Ethics Committee (EMS-REC)

7.3 APPENDIX C – TITLE REGISTRATION LETTER

Private Bag X1290, Potchefstroom
South Africa 2520

Tel: 018 299-1111/2222
Fax: 018 299-4910
Web: http://www.nwu.ac.za

Higher Degree Administration
Tel: 018 299 2626
Email: 21711542@nwu.ac.za

10 November 2021

Dear Mr Taylor

REGISTRATION OF TITLE

Note has been taken that you wish to submit your (mini-)dissertation/thesis for examination. The registered title as it must appear on the examining copies and on the title page of the final copies is indicated below. An example of your title page will be sent together with this letter.

Analysing operational cost performance in selected gold mines in South Africa

The above-mentioned title may under **no circumstances** be changed without consulting your supervisor and obtaining the approval from the relevant committee in the mentioned faculty, in regard of which this office must be furnished with the latest approved title.

In the instance that you wish to submit for examination, please inform your supervisor/promoter accordingly. *Also ensure absolute adherence to the prescripts of A Rule 4.10 for the submission of a Master's study and of A rule 5.10 for the submission of Doctoral thesis.*

Please notify me and your supervisor/ promoter if you are unable to submit for examination, as this would affect the schedule of your examiners expecting your copy for examination.

Your attention is drawn to the following matters regarding the above.

- You may submit your examination copies from **20 September 2021 to 10 December 2021, to possibly qualify for the May/June graduation ceremony in 2022.**
- **Submissions received after 10 December 2021 will be considered in time for examination towards possible graduation during the July/August 2022 graduation series and re-registration for 2022 will be required.**

You are required to submit your examination copy in the following format:

- **One electronic copy in Word format and one electronic copy in PDF format to be submitted in a drop box created for you for this purpose on the eFundi website on Higher Degrees MBA - 2021. You may also submit via email, or in person, over the counter to an HDA official.**

The following forms must be submitted with your examination copies:

- **The signed Solemn Declaration form**
- **TurnItIn report (Only the summary)**
- **Copy of your ID**
- **Personal particulars form (only applicable for PhD students)**

Please visit the DIY Student 360° to ensure that your personal details are correct.

Visit the Personal Detail on DIY to update your information. Please update your courier address to ensure that your degree certificate will be sent to the correct address after a ceremony.

Please visit the overview tab on eFundi HIGHER DEGREE – MBA 2021 for more information with regards to submission.

For ease of reference, herewith a reference to the following useful resources:

- General Academic Rules (A-Rules):
- Manual for Master's and Doctoral Studies:
- Policy on academic integrity:
-

I trust you find the above in order. Please do not hesitate to contact the undersigned for any more related information.

Yours sincerely

Ms N Blom
for REGISTRAR

Original details: (10812187) M:\HDA Toolbox\Phase 2\1 Title Registration\Title registration letter.docm
22 February 2018

File reference: 7.1.11.1

7.4 APPENDIX D – EDITING CERTIFICATE

Coordinators: Wendy Barrow & Sarita Antunes
Tel: 016 910 3485
E-mail: wendy.barrow@nwu.ac.za
sarita.antunes@nwu.ac.za

19 November 2021

EDITING CERTIFICATE: 21-301

To whom it may concern

This letter serves to confirm that the article/dissertation/thesis with the title: **Analysing operational cost performance in selected gold mines in South Africa** has been language edited by the *Centre for Translation and Professional Language Services* (CTrans). CTrans is a registered corporate member of the South African Translators' Institute (SATI) that makes use of qualified and experienced language practitioners to provide professional translation and language editing services.

CTrans hereby acknowledges that the document has undergone a proper and professional language edit (including the checking of spelling, grammar, register and punctuation). The onus rests on the client to work through the proposed changes after the edit and accept or reject these changes.

Yours sincerely

Wendy Barrow

CTrans Coordinator

7.5 APPENDIX E – STUDENT ID

THE BEARER MUST COMPLETE THE PARTICULARS BELOW: LE TITULAIRE DOIT REMPLIR LES DETAILS CI-DESSOUS

Bearer's place of permanent residence / Résidence principale du titulaire

Street — Rue: 1 Kolgans street

Place — Lieu: Potchefstroom

Country — Pays: South Africa Telephone — Téléphone: +2782 455 9284

In case of accident or death notify: / En cas d'accident ou de décès, prière d'aviser:

Name — Nom: Dalene Wagner

Relationship — À titre de: Partner

Street — Rue: 1 Kolgans street

Place — Lieu: Potchefstroom

Country — Pays: South Africa Telephone — Téléphone: +2783 626 9487

Signature of bearer — Signature du titulaire

REPUBLIC OF SOUTH AFRICA   REPUBLIQUE D'AFRIQUE DU SUD

PASSPORT PASSEPORT

Type: PP Country: ZAF Passport No.: 463381209

Surname: TAYLOR

Given names: STANLEY

Nationality: SOUTH AFRICAN / SUD-AFRICAIN

Date of birth: 05 09 1969 Identity No.: 6909055051086

Sex: M Place of birth: SOUTH AFRICA

Date of issue: 23 10 2006 Authority: DEPT OF HOME AFFAIRS

Date of expiry: 22 10 2016

PPZAFTAYLOR<<STANLEY<<<<<<<<<<<<<<<<<<<<<<<<<

4633812098ZAF6909057M1610224690905505 1086<42

7.6 APPENDIX F – TURNITIN REPORT

turnitin

Digital Receipt

This receipt acknowledges that Turnitin received your paper. Below you will find the receipt information regarding your submission.

The first page of your submissions is displayed below.

Submission author:	STAN TAYLOR
Assignment title:	Your turnitin report
Submission title:	26316919:26316919_-_Stan_Taylor_MBA_Mini_Dissertation_-_...
File name:	cc_26316919_-_Stan_Taylor_MBA_Mini_Dissertation_-_01_Dec...
File size:	10.99M
Page count:	96
Word count:	12,365
Character count:	67,938
Submission date:	30-Nov-2021 02:12PM (UTC-0800)
Submission ID:	1716755346


NWU

Analysing operational cost performance in selected gold mines in South Africa

S Taylor

Turnitin Originality Report

Processed on: 01-Dec-2021 [illegible]
ID: [illegible]
Word Count: [illegible]
Submitted: 1

Similarity Index
7%

Similarity by Source
Internet Sources: [illegible]
Publications: [illegible]
Student Papers: [illegible]

26316919:26316919_-_Stan_Taylor_MBA_Mini_Dissertation_-_01_Dec_21.docx By STAN TAYLOR

1% match (student papers from 16-Nov-2021)
Class: bd171c51-[illegible]
Assignment: Portfolio of Evidence Exam
Paper ID: [illegible]

1% match (Internet from 19-Sep-2021)
[illegible]

1% match ()
[illegible]

< 1% match (student papers from 12-May-2021)
Submitted to Liverpool John Moores University on 2021-05-12

< 1% match (student papers from 20-Nov-2020)
Submitted to University of Limerick on 2020-11-20

< 1% match (Internet from 02-Jul-2019)
[illegible]

< 1% match (Internet from 08-Nov-2021)
[illegible]

< 1% match (Internet from 08-Aug-2019)
[illegible]

< 1% match (Internet from 29-Jan-2019)
[illegible]

< 1% match (Internet from 18-Nov-2021)
[illegible]

< 1% match (student papers from 30-Nov-2017)
Submitted to Heriot-Watt University on 2017-11-30

< 1% match (student papers from 18-Aug-2020)
Submitted to Heriot-Watt University on 2020-08-18

< 1% match (Internet from 22-Sep-2021)
[illegible]

< 1% match (student papers from 25-Apr-2016)
Submitted to Saint Leo University on 2016-04-25

< 1% match (student papers from 12-Mar-2021)
Submitted to University of Salford on 2021-03-12

< 1% match ()
[illegible] Wikipedia, en, 2021

< 1% match (student papers from 11-Nov-2018)
Submitted to Mancosa on 2018-11-11

< 1% match (Internet from 05-Aug-2020)
[illegible]

< 1% match ()
[illegible] "Consumer Attitude Towards Mobile Advertising And Purchase Intention", UTAR, 2015

< 1% match (student papers from 27-Aug-2014)
Submitted to The University of Manchester on 2014-08-27

< 1% match ()
[illegible], T. "DEVELOPING GLOBAL LEADERSHIP COMPETENCIES IN JAPANESE MULTINATIONAL MANUFACTURING COMPANIES (JMMC)"

< 1% match (publications)

Cynthia Snedeker. "PMP® Certification All-in-One for Dummies®", Wiley, 2011

< 1% match (student papers from 07-May-2021)
Submitted to University of College Cork on 2021-05-07

< 1% match (student papers from 22-Nov-2020)
Submitted to University of the Free State on 2020-11-22

< 1% match (Internet from 18-Nov-2018)
[illegible]

< 1% match (student papers from 06-Mar-2006)
Submitted to City University of Hong Kong on 2006-03-06

< 1% match (student papers from 03-Mar-2017)
Submitted to University of Mauritius on 2017-03-03

< 1% match (Internet from 17-Sep-2017)
[illegible]

< 1% match (student papers from 15-Feb-2019)
Submitted to Singapore Institute of Technology on 2019-02-15

< 1% match (student papers from 04-Oct-2021)
Submitted to University of Southern Queensland on 2021-10-04

< 1% match (student papers from 09-Nov-2021)
Submitted to American InterContinental University on 2021-11-09

< 1% match (Internet from 13-Apr-2019)
[illegible]

< 1% match (Internet from 07-Feb-2020)
[illegible]

< 1% match (Internet from 14-Dec-2018)
[illegible]

< 1% match ()
[illegible] "Knowledge management practices in local government : the case of the City of Johannesburg", Stellenbosch : Stellenbosch University, 2019

< 1% match (Internet from 30-Aug-2017)
[illegible]

< 1% match (Internet from 18-Jan-2014)
[illegible]

< 1% match (student papers from 20-Aug-2013)
Submitted to London School of Commerce on 2013-08-20

< 1% match (publications)
[illegible] "A better project performance prediction model using fuzzy time series and data envelopment analysis", Journal of the Operational Research Society, 2017

< 1% match (Internet from 13-Aug-2018)
[illegible]

< 1% match (Internet from 08-Nov-2021)
[illegible]

< 1% match ()
[illegible] "Malaysian Listed Firm's Tax Avoidance: Another Earnings Management Strategy?", Asian Academy of Management, 2015

< 1% match (Internet from 23-Jul-2021)
[illegible]

< 1% match (Internet from 31-Mar-2021)
[illegible]

< 1% match (Internet from 08-Sep-2017)
[illegible]

< 1% match (Internet from 08-May-2020)
[illegible]

< 1% match (student papers from 17-Nov-2021)
Submitted to Durban University of Technology on 2021-11-17

< 1% match (student papers from 28-Aug-2020)

Analysing operational cost performance in selected gold mines in South Africa 9 Taylor orcid.org/0000-0002-0628-4628 Mini-dissertation submitted for the degree Master of Business Administration (MBA) at the North-West University Supervisor: Prof Johan Jordaan Examination: 10 December 2021 Student number: 26318919 I ABSTRACT Gold mines are essential for the economic well-being of South Africa. It is a job creator and contributes billions of Rands in taxes. South Africa has always been the leader in gold production, but performance has lacked in the past fifteen years. The studies goal was to determine the benefits of using Earned Value Management (EVM) as a tool to track progress and cost on operation cost and to demonstrate its potential benefits. This study was conducted on ongoing-capital-development and stoping parameters with data over the past three years. Further to the physical tracking of the progress, this study demonstrates how effectively EVM can forecast both the Estimated Cost at Completion (EAC) and Schedule at Completion (SAC) when financial budgets and production targets are planned over a longer duration. The EVM methodology gives the manager an understanding of where the progress may end if the current performance regarding cost and production is maintained. During my employment in capital projects over the past 25 years, I could never understand the need for managing operational costs and capital costs differently. The operating cost planning is done in much more detail but only executed over a year. This funding is called "working cost" and is approved annually. Capital planning is in minor detail, but the budget is approved for longer durations. The project team must complete all deliverables within the extended time frame with approved funding over an extended period. When comparing these two costs, the working cost on a production mine is much higher than the capital, and should these costs be ill-managed, it is likely to have more significant consequences. This study demonstrates the benefit of Earned Value Management (EVM) on operational cost. If any deviations are noted early, the potential impact that may be caused is reflected in the cost and production management. No previous research on this management methodology on working costs was found. This study is quantitative and is fact-based, calculated with actual data from a mine. The findings demonstrate that millions of Rands can be saved by implementing EVM. 8 KEY TERMS Key terms used in this research with descriptions: i. Earned value management "Earned value management (EVM) is a powerful methodology that gives executives, project managers, and other stakeholders the ability to visualize project status throughout the project life cycle and consequently manage projects, programs, and portfolios more effectively" (Anbari, 2011). ii. Ongoing-capital-development (OCD) Process of accessing an orebody through tunnelling in underground mining operations. These tunnels are on average 3 m wide and 3 m high and can be km's in length. iii. Stoping (Encyclopaedia, 2021) It is extracting ore via underground processes. iv. Capital projects Capital is funded by investors and is used for the expansion (increase production volumes), replacement (sustaining production volumes), and Stay-in-business (safety and production integrity assurance) processes. v. Operating cost Supply financing for the operational expense to produce gold. ACKNOWLEDGEMENTS I am grateful to my Creator and all for giving me the mental and physical ability to do a Mini-dissertation and an MBA at my age. Thank you for giving me the opportunity and guidance during such a privileged period of my life. A special thanks to all members of management at the mine for making their time and resources available to me. Thank you to the group COO, the Senior Accountant, and the Senior Mine-Planner for granting me permission to use their data. II TABLE OF CONTENTS ABSTRACT

.... 85 viii ABBREVIATIONS List of abbreviations as per the table below. Table 1: List of abbreviations Abbreviation Meaning AC Actual cost ACWP Actual cost work performed BCWP Budgeted work performed BCWS Budgeted work scheduled CAD Computer-aided design Cap Capital Capex Capital expenditure CPI Cost performance ratio CV Cost variance EAC Estimate at completion EV Earned value EVM Earned value management IRR Internal rate of return ITC Indicated total cost kg Kilograms km Kilometres LOM Life of mine lvl level LOM Life of Mine m² Square meters (centares) m³ Cubic meters mcf Mine call factor m metres Moz's Million ounces NPV Net present value Opex Operation expenditure OCD Ongoing-capital-development ORM Ore reserve management Oz. ounces lx Abbreviation Meaning PMBOK Project Management body of knowledge PV Planned value R South African Rands SPI Schedule performance ratio SV Schedule variance SWP Summary work packages t ton WBS Work breakdown structure $ United States of American Dollars x 1 CHAPTER 1 – CONCEPTUALISATION OF THE RESEARCH 1.1 INTRODUCTION The research objective is to determine if Earned Value Management (EVM) can play a proactive role in managing operational costs regarding cost savings and increased production in the gold mining industry. With 25 years of experience in project management in the mining sector, I have the required knowledge to research this topic. The results of this study will positively contribute to the gold mining sector and will prolong job security, and ensure stakeholder benefits. The research can be adopted for any mine as the cost and production methodologies remain the same. The mine that supplied the research data (cost budgets, production targets, and actual achievements) will remain anonymous as it may harm the shareholders' perception of this sensitive data. The mine will be called "A-Mine" for the purpose of this study. This chapter provides the background of the SA gold mining industry as well as the problem statement. 1.2 BACKGROUND AND HISTORY OF SA GOLD MINES Gold was first discovered in South Africa on the banks of the Witwatersrand by Jan Gerrit Bantjes in June, 1884 (History, 2016). Figure 1: Witwatersrand basin area (Blue) (Mining, 2021) Jan's father, Jan Gerritze Bantjes, was the Secretary General of the Voortrekkers and was the author of the treaty (04 February 1838) between the Zulu king (Dingane) and the Voortrekkers' leader (Andries Pretorius) (Guide, 2021). South Africans currency derives from the name "Witwatersrand," an Afrikaans word (CANDA, 2020). The term "rand" directly translates to English as "ridge" or "reef". Figure 2: South African 1 Rand coin (Club, 2021) The Witwatersrand basin covers a significant area of South Africa, and the central location is demonstrated in Figure 1, highlighted in blue. More than 1.5 billion ounces of gold (40,000 tonnes) (Mining, 2021) was produced in this area. The basin' area is close to 350 km from the North-East to the South-West direction in length. This reef is solely responsible for approximately 30% of all the gold ever produced in the world to date (Harper, 2020). Figure 3: Gold miners during the gold rush (Artifacts, 2021) There are currently 86 gold mines operational in South Africa (IQ, 2018), of which most are underground operations. Access to ore bodies is mainly through open-pit mining, decline shafts or ramps, vertical shafts, or a combination of all. Figure 4: Mining access options (Viewpoint, 2021) Currently, Mponeng mine, owned by Harmony Gold, is officially the deepest mine in the world. The mine's operations extend past 4 km (Gold(B), 2021) below the surface. The three primary gold-producing companies in South Africa are Goldfields, Harmony Gold, and Sibanye Stillwater. The remaining total resources available at their most significant operations are: a) Goldfields (Goldfields-Southdeep, 2021). ? South Deep – 912,885 kg (32.2 million Oz) b) Harmony Gold (Gold(A), 2021). ? Tshepong operations – 798,000 kg ? Target 1# – 113,000 kg ? Doornkop – 227,000 kg ? Kusasalethu – 184,000 kg ? Mponeng – 733,000 kg ? MOAB Khotsong – 386,000 kg c) Sibanye Stillwater (Stillwater, 2021). ? Kloof (all operations) – 932,839 kg (32.9 million Oz) ? Beatrix (all operations) – 311,848 kg (11.0 million Oz) ? Driefontein (all operations) – 320,360 kg (11.3 million Oz) The mining sector, including all commodities, contributed R 400 billion to the GDP of South Africa during 2020 (Accrana, 2021). This contribution was 8.2 % of South Africa's total GDP for 2020. The mining industry has, in the past, contributed 21% of South Africa's GDP during the 1980s (Sutherland, 2021). Does this mean the gold resources have depleted, or did South Africa's proud mining heritage die? Graph 1: Revenue per mining sector 2020 (Garside, 2020) The gold mining sector contributed 14% of the total revenue realised by the mining sector, as seen in Graph 1. The mining sector has also secured employment for 451,427 people (Garside, 2021). Gold mining has employed 20.7% of the total mining employees during 2020, and finding a method to increasing sustainability is becoming more critical. Graph 2: Employees per mining sector (Garside, 2021) South Africa was the leading gold producer in the world until 2006 (Wikipedia, 2021). As seen in Graph 3, other countries have steadily explored opportunities and increased their production to become world-leading producers, leaving South Africa behind. Graph 3: World Gold production – 2020 (GoldHub, 2021) Areas that influence the mining profitability and success in South Africa are mostly (Lamal, 2015) related to: ? Rand / $ exchange rate; ? political interference; ? commodity prices and rising production costs; ? increased labour and energy costs; ? constant demands from employees and unions; and ? government expectation that mines should fulfil social needs. The importance of South Africa's mining sector is evident. Any solutions that may enhance the mining operation must be studied. These solutions are not limited to the actual mining below the surface but can also be more innovative in management. Graph 4: South Africa declining gold production (CEIC, 2021) South Africa's highest recorded annual gold production was 619.2 tonnes during 1993. The lowest ever gold production for South Africa was during 2020, with only 90 tonnes (CEIC, 2021). Although Covid-19 most certainly played a role in this poor production year, 2019 (without any pandemic) also recorded a low production achievement of 105 tonnes. Gold has always been a good investment during stages of political and economic uncertainty. Gold consumption in the world is as follow (Economics, 2021): ? Jewellery – 50%. ? Investments – 40%. ? Industries – 10% Graph 5: Gold price history $ per Ounce (Economics, 2021) There is no question that gold mining remains an excellent investment for shareholders. As shown in Graph 5, the gold price has performed very well over the past 50 years. When analysing Graph 4 and Graph 5, South Africa is economically losing out as the gold price is reasonable, but our gold production is not where it should be. As shown in Figure 5, in the two industries where unions play a significant role, the consequences of their parts are evident. The damaging effect that unions play in the manufacturing and mining sectors requires urgent intervention. Manufacturing has moved from contributing 22% of our annual GDP to 13%; and mining has moved from being a 21% contributor to a mere 8% (StatsSA, 2017). Figure 5: The decline of mining and manufacturing in South Africa (StatsSA, 2017) This study aims to determine the potential benefits of an Earned Value Management (EVM) approach on ongoing-capital-development (OCD) and stoping areas. An EVM approach is used mainly on capital projects and still needs to find its place within working costs. Finding a methodology for managing a mines' performance better within the operational cost could help secure better stakeholder value. South Africa's gold-mining industry must determine why it lost its competitive advantage when comparing production performances to the rest of the world. The reasons may be depleted orebodies, unproductive workforce, old technology, union involvement, or poor management. For this study, the focus is on management methodology. 1.3 PROBLEM STATEMENT 1.3.1 Operational cost management (Rand) The achievements of the operational cost expenditure versus the approved budget is an area of concern as it is believed that the duration of the cycle may be too short (currently twelve months) or is bound to be a too-small portion of the total scope of work. Mining operational costs are approved annually, and the extent of any deviations during a specific year does

not reflect the effect throughout the remainder of the mining operation. Overspending annually is easily overseen as the new year will bring a new budget that will not consider the previous year's poor achievements. The account holders are only responsible for one year's expenditure achievement and not the complete scope deliverable. The compound effect is never taken into consideration from one year to another. 1.3.2 Production performance (Metres, tonnes & m2) The same concern raised within the operational cost management is evident in the production performance. Mining production activities are also managed annually. If poor production achievements were achieved versus its planned targets, the underachievement would be written off, and the net effect it caused in the larger plan is never dealt with. The two main areas that are applicable are: I. Ongoing-capital-development (OCD) – This activity establishes new tunnels to the reef horizons. The purpose is to create new routes to give men and material access to the mining area (stope – see below). If the ore extraction (stoping) starts later than planned due to these ends being late, the gold production will be late, and value is destroyed. The OCD tunnels are designed and measured in metres. The achievements are measured monthly by surveyors and logged into a database. These ends are usually 3m high and 3m wide and can be more than 5 kilometres long. With the rock density of 2.78 tonnes per m3 taken into consideration, each metre developed (9 m3) produces 25.02 tonnes of ore to be transported to the surface. II. Stoping – Stoping is the terminology used for the mining of the ore-bearing area. The OCD ends are the route to these mining areas. As mentioned above, this activity may start later than planned due to delays in OCD areas, and the revenue loss can compound if the same challenge occurs and production targets are not achieved. The OCD and stoping areas can cause significant financial losses due to unmet targets, which requires mitigation. Underperforming in these areas is easily overseen as the new year will bring along a new set of targets that will not consider the previous year's poor achievements. The compound effect is never taken into consideration from one year to another. Figure 6: Sefateng mine layout (Cornish, 2015) In Figure 6 (stoping panels – pink), the delayed production on the stoping can be understood if OCD production is late. In this example, the marked OCD end is 3.1 km long and scheduled at an advance of 60 metres per month. If all goes according to plan, it will take 4.3 years to reach the mining operations on the western side. Each OCD metre not achieved will cause the stoping of a specific block to be late. The same scenario will be if the stoping at 180m from the bottom to the top level occurs. The problem investigated in this study is the mines production performances that may be underperforming and the associated costs that may be overspending. With the available historical data of the abovementioned problem statement, the data will be used to determine whether the application of EVM on operational cost can enhance profitability in the mining sector. This study will evaluate if EVM can: ? ensure better production achievements; ? increase the effectiveness of cost management; ? proactively forecast cost and production trends; and ? increase the profitability of the organisation. When comparing the operating cost to any other expense on a mining project, the following is evident: ? Operating cost has a higher sensitivity risk than capital, as can be seen in Graph 6. This higher risk means that the effect of overspending working cost targets will corrode the committed financial return promised to investors. There is thus less room for error when compared to capital. In contemplation of the sensitivity analyses, the impact of improved cost and value management could be considerable. Graph 6 is from a feasibility study previously done for A-Mine. The evaluation reflects that if the expenditure is 5% more than planned, the effect will be –5.9% on the IRR (14% to 8.1%). On the positive side, if the expenditure is 5% less, the effect will increase by 7% (14 % to 21%). Graph 6: Sensitivity analysis (A-Mine) ? Operating cost attracts the highest monetary value, as can be seen in Graph 7. Graph 7: Cost weighting between various areas (A-Mine) ? The operating cost has the most extended scheduled duration seen in Graph 8. Capital funding creates infrastructure to open the ore body. Once in production, the operational cost will be made available to pay for mining operations. Graph 8: Cost forecast per area (A-Mine) The opportunity lies in the operational cost and OCD areas by implementing project management tools over extended periods. This strategy will ensure production personnel are responsible for larger mining production targets and reflect on the current status of a specific area within the more extensive plans. With the available information, this research will determine the following: - Is the operating cost being managed to the best of the mine's ability? - Are the current methods used effectively? - Will there be any benefit in managing the cost and production by using EVM? Mining houses' problem is that the operating cost areas are managed and measured year-to-year. The under-performance on production and over-expenditure just for convenience's sake is forgotten and swept under the carpet. As illustrated in Table 2, the example shows the challenge and opportunity that must be addressed in the operational and OCD areas. This study will determine if a problem exists concerning the performance of stoping and OCD areas and how the expenditure compares with the achieved performance. If the outcome indicates the need for better tools, this study will illustrate the benefits of using EVM. An EVM approach may solve this issue of integrating the scope with its cost and schedule, and it can pro-actively determine the current cost and production profile in the future based on the actual achievements now. Accountants and planners can take corrective action only if they understand where it is required; EVM will reflect on these high-risk areas, whether cost or schedule. Table 2: Illustration of impact on underperformance and overspending 1.4 RESEARCH OBJECTIVES The main objective of this research is to demonstrate the effectiveness of using EVM on working cost activities by comparing production and cost figures using traditional and EVM costing scenarios. The following specific research objectives will support this: ? to understand the essence of EVM as a cost management tool through a literature study, ? to compare OPEX calculations based on traditional and EVM approaches using historical figures, and ? to create an OPEX dashboard using the EVM approach. Specific objectives in this research focus on the following: ? Breaking down the operational cost at a higher but more adequate level of control. ? Creating a dashboard by showing the ease of reporting and visibility of variance results. ? Focusing on more extended budget and planning life cycles and abandoning short- term (12 months) plans. 1.5 HYPOTHESIS The importance of this contribution will be to identify the positive contribution using EVM on working costs can make to the overall strategy of making a mine more successful and sustainable. The goal is to demonstrate the level of impact the implementation of EVM can have when implemented as a management strategy. The benefits that are demonstrated through this study is that by using EVM, the mine will: ? decrease its operating cost expenditure (increase efficiencies); ? increase its production rates due to better focus on the bigger picture; and ? increase profitability. Essentially, EVM allows the user to work smarter and not harder. The question also needs to be asked, why the need for this research? The answer, in short, is: ? This research can become a game-changer in the mining industry. ? Using EVM can create real value for all stakeholders. ? EVM is a proven management strategy. EVM has not found its place yet in all management structures as the perception is that it is only a project management tool. Table 3: Demonstration of the importance of each deliverable The demonstration in Table 3 reflects the importance of each deliverable within the larger picture. Each area on its own, if overspent or under-produced, influences the total deliverable. Although a unit of 10 is insignificant compared to an entire scope of 1,200 units on its own, it remains 0.83% of the complete area. When a production section completes the year and has underperformed by, for instance, 10% and has simultaneously overspent its budget by 10%, the effect of this performance on the following years' plan is not captured. As seen in Graph 6, the operating cost has a significant impact on the promised returns needs to

investors using net present value (NPV), internal rate of return (IRR) and payback periods (Plaksenovich, 2021). Not controlling the total cost and production packages throughout the area is an imperfect system that does not ensure investors' assets are protected and the actual value for their investment may not be achieved. Alternative strategies must be determined and used to create better value for all stakeholders and minimise the risk of failure. 1.6 VALIDITY AND DEPENDABILITY Audited production plans, cost budgets and actual achievements are made available by A-Mine for the study. Mine planners compile the production business plans (BP) by using specialised software and data models. These plans were presented to the organisations' executives and have been approved. The actual achievements of these production areas were measured by qualified surveyors and approved by the mine's Mineral Resource Manager. The cost accountants calculate the financial business plan (BP) and determine the production profile's cost. An accounting system captures all financial transactions and expenditures. The financial manager and the organisations' auditors verify the achievements. From a dependability point of view with regards to the author's background to conduct the study is because: ? it falls within the researchers' skills and knowledge; ? the researcher has 28 years of experience on projects and 20 years in the mining field; ? this area is where real change can be implemented; and ? this area has the lowest level of effort, yet it can have maximum impact. 1.7 CONSTRAINTS Ideally, this study should be done in detail where specific detailed levels can be exposed. Unfortunately, due to the time and data made available by the mines personnel and the limitation on social interaction on the premises of the mine due to Covid-19 regulations, a decision was made to conduct the study in a higher level of detail than initially anticipated. Figure 7: Illustration on level of activities The ideal level of activity is illustrated in Figure 7 as lvl 3. The information and data used were on a summary level 1. The information remains adequate to determine and demonstrate the outcome. The challenge may be that the net effect is small, but on analysing the detail, certain areas are further from the mark but not shown in summary due to better performance by other areas. The effect will not be visible on a summarised level. An illustration of studying a summarised sample is demonstrated in Table 4. Table 4: Illustration of summarised sample challenge Although the total value reflects that all is on target on the summarised level, one area may compensate for the other's poor performance, causing a misleading reality. 1.8 ENGAGEMENT WITH MINE PERSONNEL The following ethical principles were followed when engaging with the mine personnel: ? Principle 1 – Minimising the risk of harm. o Social disadvantage – I will be cautious when errors in the data are found so that the people responsible for this work do not feel threatened. A very diplomatic approach will be required. o Invasion of participants' privacy – Data collected and information shared will be handled with strict confidentiality. ? Principle 2 – Obtaining informed consent. o I have initiated a kick-off meeting with all relevant stakeholders of this research. Written consent has been obtained from the mine's corporate office. ? Principle 3 – Protecting anonymity and confidentiality. The conditions of management's approval will be observed. o All data will be kept confidential. o All discussions (formal and informal) with personnel will be kept confidential. ? Principle 4 – Avoid deceptive practices. o Personnel supplying me with the data will be aware of what they are doing, why they are doing this, and what study results may be. o I will remain objective with no preference to what the research outcome may be. o All data will be integrated into an EVM system. ? Principle 5 – Providing the right to withdraw. o I have ensured the organisation that they may withdraw at any time. 1.9 CHAPTER SUMMARY Gold mines have played an essential role in the economy of South Africa. It has created not only wealth for a few but has been a means of income for millions of South Africans over the past century. Because of gold, our country's infrastructure was built, and a striving economy was established. South African miners were seen as the best miners in the world. This research wants to give back to the mining community. I will be delighted if a method exists that may help produce for a while longer, keeping a breadwinner for an additional year or two on the payroll. 2 CHAPTER 2 – RESEARCH METHODOLOGY 2.1 RESEARCH DESIGN CLASSIFICATION The research conducted is classified as a quantitative research design. The mine's data from the past three years (2018 – 2020) was collected, and a restated document reflecting the planned development targets and the planned budgets for these areas was compiled. A technical, numerical approach was used as the data is cost and schedule orientated. The cost planning and actual achievement information were made available from the mine's accountant, and the mine planner supplied the production targets and achievement. These parties were not directly involved in the study but merely executed management's decision to supply production and financial data. The data supplied by the mine form the data set to be analysed. The study determines and demonstrates if a benefit is possible by using EVM on managing cost and production. All planned production with associated costs has been scrutinised and compared with the actual achievements. All eleven quantitative research processes were effected during the research planned, namely (Thompson, 2017): I. Theory II. Hypothesis III. Research design IV. Operationalising concepts V. Selection of research site VI. Selection of respondents VII. Data collection VIII. Processing data IX. Data analysis X. Findings and conclusions XI. Writing up of results. Further to above, a quantitative research design has been adopted because: ? it offers to focus on the researcher's viewpoint, ? theories and concepts are tested; ? a structured data collection process has been conducted; and ? data are reliable and factual. Table 5: Cross-sectional vs Longitudinal study (Akhaari, 2020) As shown in Table 5, based on the leading indicators of Cross-sectional and longitudinal, the study is a longitudinal study. The reasons for conducting a longitudinal study are due to: ? Study timelines over multiple points in time: o month o year o Three years ? The sample type will be the same on all measurements: o Production achievements – Metres, m3 or tons (target vs actual) o Cost performance – Rands (budget vs actual) ? The results will show the details of its changes over time. The analyses will reflect the cost and production performances on an incremental and cumulative basis. 2.2 METHOD OF DATA IMPLEMENTATION The study data is databased, investigational, simulated, and sourced from A-Mine. Understanding how the mine conducts its production planning and associated budget models were required to be understood in detail. Further to the planning process, filtering the correct detailed actual achievements from the production cycle and expenditure achievement required a good knowledge of the data. Figure 8: Data implementation process (Paint, 2021) The aim was to reflect if, at any given time in the past three years, the Estimate at Completion (EAC) could predict the outcome if the current trend on production and cost (positive or negative) is not corrected. Graph 9 shows an example of EAC. The formula for achieving this result is the following: EAC = ((Total Planned Value – Earned Value) / Cost Performance Ratio) + Actual Cost Graph 9: Estimate at completion explanation (Reeslee, 2018) The Earned Value and Cost Performance Ratio was measured at a specific time (increments) and varied to establish the particular outcomes. The outcome and deliverables that integrate all the relevant information into EVM will be as per the examples below. Table 6: EVM example summary (CPR, SPR, CV & SV) Table 7: EVM example summary (PV, EV & AC) Graph 10: EVM example Graphs (PV, AC & EV) To conclude, the aim was to determine the following with all relevant data received: i. PV – Planned Value (Determine the monetary value of the planned and scheduled production over the pre-determined duration). ii. EV – Earned Value. Calculate the actual monetary value of work performed/achieved. iii. AC – Actual Cost. Include the actual expenditure to the correct allocated scope of work. iv. CV – Cost Variance. Determine what the deviation between the earned work and actual expenditure is. v. SV – Schedule Variance. Determine the deviation between the earned work and the actual plan. vi. CPR – Cost Performance

Ratio. A ratio above 1 indicates that earned work is done at a lower cost than planned, and a ratio less than 1 suggests an over- expenditure on earned work performed. vi. SPR – Schedule Performance Ratio. A ratio above 1 indicates that earned work is ahead of the planned schedule, and a ratio less than 1 indicates an underachievement on the schedule on earned work performed. vii. EAC – Estimate at Completion. The final estimated cost if the current performance remains. ix. SAC – Schedule at Completion. The duration when the current performance remains. The variance will be in months over or under the original plan. Since the study involves the analysis of existing data, there is no direct human involvement and no "sampling" in the traditional sense. Data will be made available with the consent of management by those people who are officially in charge of the data. The personnel who will assist me with the following are: o Snr Project Manager; o Snr Accountant; and o Snr Mine Planner. This research's objective will establish what benefits or different outcomes Earned Value Management will have if used as a management tool. I, therefore, use historical data as a predictor for future benefits. Data analysis is defined as "a process of cleaning, transforming, and modelling data to discover useful information for business decision-making. The purpose of data analysis is to extract useful information from data and make the decision based upon the data analysis" (Johnson, 2021). The validity and reliability of the data are accurate as only audited data will be used. 2.3 AREAS EARMARKED FOR RESEARCH Mining has a large footprint on the surface as well as underground. The main areas in a typical deep level gold mine are: ? Mine o Headgear – Concrete or steel headgear that houses the hoist wheel (sheave). o Winders – Mechanical mechanism used transporting men, material, and ore in the shaft barrels up and down. o Shaft barrel – As per above and to accommodate all services required underground (air, water, electricity, etc.). o Pump stations – Pumping of all water back to surface from underground. o Fridge plants – Cooling recirculated water underground to be used to cool mine underground. o Access development ends – Forms the "highway" from the shaft to the mining infrastructure. o Ongoing-capital-development ends – Forms the routes from the "highway" to access the orebody. o Stopes – Reef carrying orebody. ? Surface storage facilities o Tailing's storage facility – TSF is a waste product from the gold plant from crushed, milled, and processed rock. o Rock dump storage facility – Development on non-reef bearing areas is hoisted to the surface and disposed of here. The research will be done as per "ongoing-capital-development" and "stopes". Figure 9: Mine layout (shaft and dev), Rock dump (Martin, 2021), and Tailing storage (Dreamstime, 2021) 2.4 ANALYSIS OF DATA The analysis was done by sourcing the mines BP2018 (business plan 2018), which was compiled and approved during 2017. This data includes all the production plans and associated cost budget for the duration until the mine will not be able to produce gold anymore profitably. This total duration is called a "Long Term Plan" (LTP) or a "Life of Mine" (LOM). The detail is done in annual increments and scheduled accordingly. Once this LTP is approved, the data for the first three years are detailed, and production plans and monthly cost budgets plans are determined. This study will be using these same three years, which will span over 2018, 2019, and 2020. This study will set up a database with this three-year production plan on OCD and stoping budgets. From the previous step, I will use the actual performance achievements on the OCD and stoping activities and incorporate them with the original BP 2018, as shown in Table 8. Table 8: Example of how the study will analyse BP18 with actual achievements The researcher will integrate plans and actual performances, and a reactive EVM calculation will be done. This calculation will allow us to play devil's advocate by moving around the actual achievements and determining the EAC, and noting how these values would have been from the actual yearly actual expenditures. Graph 11: EVM Graph as per stoping example in Table 8 2.5 CHAPTER SUMMARY The impact on a slower than planned OCD and stoping performance can be detrimental to the total success of the mining operations. With high fixed-costs as water, electricity, labour costs, and the maintenance of the dangerous infrastructures' integrity, the mine cannot delay any production. New methodologies should be investigated to ensure better focus. 3 CHAPTER 3 – LITERATURE AND DATA REVIEW 3.1 INTRODUCTION This chapter will conduct a literature review on Earned Value Management and the benefits thereof. Further to this, the data provided by A-Mine will be reviewed. A consolidated database with the data received from the mine was constructed and compiled into a structured template to determine the results. 3.2 LITERATURE REVIEW ON EARNED VALUE MANAGEMENT Earned Value Management is a cost-engineering tool that combines any deliverable's scope, time, and money. Cost engineering applies scientific principles and techniques to estimation problems, cost control, business planning and management science, profitability analysis, project management, and planning and scheduling (AACEI, 2021). Figure 10: Cost Engineering triangle (Esg, 2021) Earned Value Management requires four fundamental control concepts. They are (Services, 2020): ? The concept of a project. Defines the scope of work to be achieved and axis parameters. ? The concept of cost engineering. ? The concept of a Work Breakdown Structure (WBS). Used to decompose the scope of work of the project into manageable elements. Figure 11: WBS Example (Wonderware, 2021) ? The concept of project scheduling. The USA department of defence initiated EVM in 1967 (Consulting, 2021). The concept was named the Cost/Schedule Control Systems Criteria Policy. The governing body of project managers, Project Management Institute (PMI) (Fostal, 2011), included EVM in the very first copy of their PMBOK (Project Management Body of Knowledge) during 1987. The Project Management Body of Knowledge guide is PMI's flagship publication and is a fundamental resource for effective project management in any industry (Guide, 2021). The Project Management Body of Knowledge guide notes EVM as being crucial for scope and cost management. 3.2.1 Earned Value Management methodology Earned Value Management is a management methodology that incorporates any program. This methodology offers all levels of management with early visibility into cost and time-related problems. Earned Value Management helps provide the basis to assess work progress against a baseline plan, relates technical, time and cost performance, provides data for pro-active management action and provides managers with a summary of effective decision making (International, 2017). The important names and acronyms used in EVM are (Reader, 2020): ? PV – Planned Value (BCWS: Budgeted Cost of Work Scheduled). Approved budget for work scheduled to be completed by a specific date). ? AC – Actual Cost (ACWP: Actual Cost of Work Performed). Actual cost realised for the work performed on a particular activity during a specific period). ? EV – Earned Value (BCWP: Budgeted Cost of Work Performed). Amount of completed work presented as the value of the performance budget allocated to that work). ? BAC – Budget at Completion. The sum of the total budgets that are expected to be spent on the performed work. ? SV – Schedule Variance. Difference between where we planned to be and where we are actually on the schedule. ? CV – Cost Variance. Difference between what was planned to spend and what was paid. ? SPR – Schedule Performance Ratio. Shows the rate at which the project performance meets schedule expectations up to a specific point. ? CPR – Cost Performance Ratio. The rate at which project performance is meeting planned costs during a particular period. ? EAC – Estimate at Completion. Shows the estimated total cost when completing all tasks. ? ETC – Estimate to Complete. It shows how much money it will need to finish the outstanding tasks of the project. 3.2.2 Earned Value Management formulas Earned Value Management uses many different formulas to determine various outcomes of the project. The following are the main formulas (Reader, 2020): ? BAC = Total Project Budget. ? EV = BAC x % Complete. ? SV = EV – PV. ? SPR = EV/PV. ? CPR = EV/AC ? SV = EV – PV ? CV = EV – AC ? EAC = BAC / CPR = AC + BAC – EV = AC – ETC = AC+ [(BAC-EV) (SPR x CPR)] ? ETC = EAC-AC ? VAC = BAC-EAC For this study, the main formulas

used are the calculation of EAC (Estimate at Completion). 3.2.3 Earned Value Management benefits Earned Value Management offers more information than standard project tracking. It proactively answers the following questions immediately (International, 2017): ? Are we on the path where we need to be in the project? ? When will we finish the project? It helps define where we are currently in the project and calculates a forecast on a completion date and duration remaining at current performance. The value-added method helps achieve greater visibility and control of the project's activities, which helps take action to ensure work on, then making it possible to meet the project timelines. It gives clear interaction of the activities involved and enhances project visibility and responsibility. The fundamental basis of EVM is that the value of the portion of work is equal to the number of funds budgeted to achieve it. 3.3 LITERATURE REVIEW AND DATA ANALYSIS ON PRODUCTION PLANNING 3.3.1 Background In the mining sector, four primary cost allocations exist. They are: I. Capital — Funds sourced from investors to establish the following: o Greenfields projects – New endeavours where no mining previously occurred. o Brownfields projects – Existing operations where projects are initiated for the following purposes: • Expansion project – The purpose is to expand the current infrastructure to increase mining capacity to realise a higher production profile. • Replacement project – The purpose is to enable the current infrastructure to sustain the mining production profile longer than initially planned. • OCD – Ongoing-capital-development to establish new mining horizons to unmined production levels. II. Sustaining capital – Capital paid to ensure safety is not compromised and investment in keeping the integrity of the mine's infrastructure. III. Operational cost – The costs provided that day-to-day mining activities are done to ensure production targets. This cost includes direct and indirect costs. Three sets of planning documents were handed over for review and analysis. These documents form the basis of all planning parameters for the mine's total production and financial planning over the remaining life of the mine. This planning also determines the comprehensive resources required monthly. It gives a state where the mine will no longer be profitable or need mitigations to push it through difficult years where a production gap (gold gap) may occur until orebodies are opened up. The documents used for data review are: I. Capital monthly pack – Detail of all capital requirements. II. Finance review pack – Detail of all operational cost requirements III. Ore reserve management (ORM) review pack – Detail of all production deliverables requirements. The ORM planning includes the planning of capital and operating costs. This study will mainly focus on the OCD and stoping planning in the "ORM review pack" and the financial planning of these areas in the "Finance review pack". These three files include a lot of detail, and a summary has been compiled with the assistance of the A- Mine's Snr Accountant. This research will focus on ongoing-capital-development and stoping, which are included in points I and III above. All areas that are seen in the ORM review pack are values derived from geological reports. 3.3.2 OCD review The summarised information for the OCD was taken from the detailed and monthly plan received from A-Mine's Snr Accountant. 3.3.2.1 Production plans and achievements The ongoing-capital-development production plans with actual achievements can be seen in Table 9 and Table 10. These development ends are, on average, 3m wide and 3m high. The main focus is only on the development and not on other costs such as Secondary Support, Raiseboring etc. Table 9: OCD production plans vs achievements – Monthly (A-Mine) The poor results during April and May, 2020 was due to Covid-19. For this study, a flex (Toole, 2021) budget was used during this period to ensure that the variances were not overstated. Table 10: OCD production plans vs achievements – Yearly (A-Mine) Although the impact of Covid-19 can be seen during 2020s total achievements, the purpose of this study remains focused on more extended periods, and 2018 reflects this. Graph 12: OCD production plans vs achievements – Yearly (A-Mine) Production shows a below-planned actual achievement when making a comparison on a cumulative basis. This study's purpose is to address this and demonstrate how EVM can assist in managing this challenge. 3.3.2.2 Budget plans and achievements It is visible that a good focus is on the cost management of the production. Table 11: OCD budget plans vs achievements – Monthly (A-Mine) Although no actual expenditure was reported over the Covid-19 lockdown period (April – July 2020), a small portion of the development was done during April (196m). The financial budget was also flexed as per the development production. Table 12: OCD budget plans vs achievements – Yearly (A-Mine) Graph 13: OCD budget plans vs achievements – Yearly (A-Mine) 3.3.2.3 OCD efficiencies Table 13: OCD Rand per Metre achievement (A-Mine) Graph 14: OCD Rand per Metre achievement (A-Mine) 3.3.3 Stoping review The summarised information for the stoping was taken from the detailed and monthly plan received from A-Mine's Snr Accountant. The stoping budget was also adjusted with a flex value as per the OCD development. This budget caters for more realistic targets over the challenging lockdown period during Covid-19 in 2020. 3.3.3.1 Production plans and achievements Table 14: Stoping production plans vs achievements – Monthly (A-Mine) A-Mine's labour force was not allowed to be on 100% during the lockdown period during April – July 2020. The stoping achievements are evidence of this. Table 15: Stoping production plans vs achievements – Yearly (A-Mine) Graph 15: Stoping production plans vs achievements – Yearly (A-Mine) 3.3.3.2 Budget plans and achievements Table 16: Stoping budget plans vs achievements – Monthly (A-Mine) Table 17: Stoping budget plans vs achievements – Yearly (A-Mine) Graph 16: Stoping budget plans vs achievements – Yearly (A-Mine) 3.3.3.3 Stoping efficiencies Table 18: Stoping Rand per m2 achievement (A-Mine) Figure 12: Stoping Rand per m2 achievement (A-Mine) 3.4 CONCLUSION 3.4.1 EVM literature review Understanding the principles of EVM is of utmost importance to conduct this study. No evidence was found where EVM is done on operational cost production areas before. This studies purpose is to demonstrate the value that EVM can add to this area of interest. For a successful study, a good understanding of how the mining plans and the execution thereof works and a good understanding of EVM methodology. 3.4.1 A-Mine data review The content, literature, and data required to do this research and analysis will be the financial and production documents used to determine the various outcomes on the mine's life, which are also sequenced into different levels (approved projects/not approved projects). This research will mainly focus on the older approved plans as the history will give the study a better understanding of the concerns. The data was made available to me by A- Mine and are available on soft and hard copy. These documents form part of the mine's long-term strategic planning process. As this information is susceptible, it will remain highly confidential and not be found in the public domain. Mining houses keep their information confidential and would prefer that their competitors do not see it. The available data is adequate for the study. The topic for the research is fact-based and could not be found to be researched before. Much research has been done on EVM and mining, but no evidence is available on these two integrated. 4 CHAPTER 4 – EMPIRICAL ANALYSIS AND RESULTS 4.1 INTRODUCTION Due to the sensitive nature of the information, an Excel database was compiled and submitted to A-Mine's Snr Accountant and Snr Mine Planner to populate with the desired information required to conduct this successful study. The following information was received from A-Mine: ? BP2018 (Business plan 2018). Includes the OCD and stoping production and budget plans for 2018, 2019 and 2020. ? OCD production achievements received for 2018, 2019 and 2020. ? OCD actual expenditure received for 2018, 2019 and 2020. ? Stoping production achievements received for 2018, 2019 and 2020. ? Stoping actual expenditure received for 2018, 2019 and 2020. This information adequately demonstrates this study's intention and how EVM can benefit the operational cost activities. The intention will be to indicate at any given time in the past three years if the Estimate at Completion (EAC) could calculate the effect if the current

trend on production and cost (positive or negative) is not corrected. As shown in Table 19, the scale will be used as a visual analysis of the specific deviation in the following segment. Table 19: Deviation scale for areas analysed 4.2 AREAS ANALYSED 4.2.1 Ongoing-capital-development The analysis was done on incremental and cumulative plans versus actual achievements on the development and costs. For the study, only the cumulative is shown as this reflects the realistic trends. The total budget over the three years was planned at R 1,097,917,233. Table 20 is the first year of the cumulative ongoing production and cost budget. 2018 will focus on months 01 – 12 of this program. Table 20: OCD – 2018 EVM Analysis + EAC OCD Cost analysis as of Dec 2018 During 2018 (the first year of the three-year investigation), the development fell behind 2,882 m (-23.8%). The total cost was underspent with R 84,834,130 million (-18.3%). The EVM calculations show a 0.90 CPR and 0.76 SPR. Using the CPR to calculate the 41 Estimate at Completion, EVM at the end of 2018 forecast if the current performance and cost trend remains, the total approved cost budget of R 1,097,917,233 can be overspent with R 120,308,598. Table 21: OCD – 2018 Schedule at Completion forecast OCD Schedule analysis as of Dec 2018 Using the SPR to calculate the Schedule at Completion in Table 21, EVM at the end of 2018 forecast if the current performance and cost trend remains, the total development planned to be completed within 36 months may take 11.2 months longer than planned. The late arrival at new mining areas will be disastrous. As explained previously, this development creates a path to new orebodies; 11.2 months can equate to hundreds of gold kilograms lost over the intended production period. Table 22 is a cumulative ongoing production and cost budget. 2019 will focus on months 13 – 24. Table 22: OCD – 2019 EVM Analysis + EAC OCD Cost analysis as of Dec 2019 During 2018 – 2019 (the first two years of the three-year investigation), the development fell behind 1,729 m (-8.7%), as seen in Table 22. Some of the deficit metres were caught up. The total cost was now underspent by R 69,563,224 million (-8.7%). The EVM calculations show a 1.01 CPR and 0.91 SPR. Using the CPR to calculate the Estimate at Completion, EVM at the end of 2019 forecast if the current performance and cost trend remains, the total approved cost budget of R 1,097,917,233 can be underspent with R 8,811,289. The mine accountants and development teams made a great effort by the production and cost team this year. Table 23: OCD – 2019 Schedule at Completion forecast OCD Schedule analysis as of Dec 2019 Using the SPR to calculate the Schedule at Completion in Table 23, EVM at the end of the 2018 – 2019 (the first two years of the three-year investigation) forecast if the current performance and cost trend remains, the total development planned to be completed within 36 months may take 3.4 months longer than planned. Production performance has closed the initial forecast completion duration with 7.8 months. Table 24 is a cumulative ongoing production and cost budget. 2020 will focus on months 25 – 36. Table 24: OCD – 2020 EVM Analysis + EAC OCD Cost analysis as of Dec 2020 During 2018 – 2020 (the total planned program), the development ended behind 2,170 m (-6.4%). The total cost was now underspent by R 125,528,221 (-11.4%). The EVM calculations show a CPR of 1.03 and an SPR of 0.92. The final summary shows an actual cost of over R 972,389,012, and development achieved realised an Earned Value of R 1,006,302,012. Although the work done was less than planned (EV vs PV), a cost-saving of R 33,913,430 was achieved over this period. Table 25: OCD – 2020 Schedule at Completion forecast OCD Schedule analysis as of Dec 2020 With the underperformance of 2,170m development over the 36 months, SPR was used to calculate the Schedule at Completion in Table 25. The EVM calculations at the end of the 2018 – 2020 forecast that due to the slower than planned achievements, the scheduled amount of metres planned initially will only be 3.3 months later. Graph 17: OCD PV vs EAC & PS vs Schedule at Completion Graph 17 shows the total EAC vs the original planned total budget as it progressed over the 36 months. The schedule at completion also reflects the forecast months the period may extend if the SPR did not increase. Graph 18: OCD Earned Value Analysis As seen in Graph 18, the PV wasn't achieved over this period. The final EVM analysis was as follows: PV: R 1,097,917,233 EV: R 1,006,302,402 AC: R 972,389,012 SV: - R 91,614,791 The less work done than initially planned equates to this value. CV: R 33,913,430 4.2.2 Stoping The analysis was done on incremental and cumulative plans versus actual achievements on the stoping and costs. For this study, only the cumulative is shown as this reflects the realistic trends. The total budget over the three years was planned at R 1,577,714,809. Table 26 is the first year of the cumulative ongoing production and cost budget. 2018 will focus on months 01 – 12 of this program. Table 26: Stoping – 2018 EVM Analysis + EAC Stoping Cost analysis as of Dec 2018 During 2018 (the first year of the three-year investigation), the stoping was ahead of plan by 5,144 m2 (+4,1%). The total cost was overspent with R 48,319,807 million (+9,6%). The EVM calculations show a 0.95 CPR and 1.04 SPR. Although the stoping was better than planned, the cost of this overachievement was much more than what was earned. Using the CPR to calculate the Estimate at Completion, EVM at the end of 2018 forecast if the current performance and cost trend remains, the total approved cost budget of R 1,577,714,809 may be overspent with R 82,730,114 if corrective action is not taken. Table 27: Stoping – 2018 Schedule at Completion forecast Stoping Schedule analysis as of Dec 2018 Using the SPR to calculate the Schedule at Completion in Table 27, EVM at the end of 2018 forecast if the current performance and cost trend remains, the total development planned to be completed within 36 months may take 1.4 months less than planned. Table 28: Stoping – 2019 EVM Analysis + EAC Stoping Cost analysis as of Dec 2019 During 2018 – 2019 (the first two years of the three-year investigation), as seen in Table 28, the stoping remained positive and ahead with 8,225 m2 (+3.7%). The total cost remained overspent and was now R 110,873,306 million (+10,7%). The EVM calculations show a 0.94 CPR and 1.04 SPR. Using the CPR to calculate the Estimate at Completion, EVM at the end of 2019 forecast if the current performance and cost trend remains, the total approved cost budget of R 1,577,714,809 can be overspent with R 107,512,096 if this trend remains without any mitigation. Table 29: Stoping – 2019 Schedule at Completion forecast Stoping Schedule analysis as of Dec 2019 The calculated Schedule at Completion shown in Table 29 at the end of the 2018 – 2019 (the first two years of the three-year investigation) period shows that if the current performance and cost trend remains, the total development planned to be completed within 36 months may take 1.3 months less to achieve the total planned stoping. Table 30: Stoping – 2020 EVM Analysis + EAC Stoping Cost analysis as of Dec 2020 During 2018 – 2020 (the total planned program), the stoping ended with 5,444 m2 (+1.6%) more production than initially planned, as seen in Table 30. The total cost was now overspent with R 175,525,929 (+11.1%). The EVM calculations show a CPR of 0.91 and an SPR of 1,01. The final summary shows an actual cost of over R 1,753,240,836 and stoping realised an Earned Value of R 1,600,615,398. Although the work done was better than planned (EV vs PV), a larger budget overrun occurred over this period. Table 31: Stoping – 2020 Schedule at Completion forecast Stoping Schedule analysis as of Dec 2020 With the over-performance of 5,444 m2 (+1.6%) stoping over the 36 months, SPR was used to calculate the Schedule at Completion in Table 31. The EVM calculation at the end of 2018 – 2020 forecast that the scheduled amount of stoping was achieved with 0.5 months less than initially planned due to the better-than-planned achievements. Graph 19: Stoping PV vs EAC & PS vs Schedule at Completion Graph 19 show the total EAC vs the original planned total budget as it progressed over the 36 months. The Schedule at Completion also reflects the forecast months the period may extend to if the SPR did not increase. It is clear that stoping costs have had severe challenges since August 2018 and have never recovered. Graph 20: Stoping Earned Value Analysis As seen in Graph 20, the PV was not achieved over this

period. The final EVM analysis was as follows: PV: R 1,577,714,609 EV: R 1,800,815,394 AC: R 1,785,240,938 SV: R 23,100,785 Due to good performance, this cost should have been saved. CV:- R 152,425,544 Over-expenditure over the 36 month duration. 4.3 SUMMARY OF OCD AND STOPING EVM ANALYSIS 4.3.1 OCD – Summary of EAC and Schedule at Completion Table 32: Summary of OCD EAC and SAC Ongoing-Capital-Development Analysis EVM Cost prediction EVM Schedule prediction Total budget Estimate at Completion Var EAC vs Budget Total period Schedule at Completion Var SAC vs period Jan 18 1 097 917 233 2 019 688 457 921 771 224 35 72,4 36,4 Feb 18 1 097 917 233 1 542 571 844 444 654 611 36 57,1 21,1 Mar 18 1 097 917 233 1 667 535 044 569 617 811 36 66,9 30,9 Apr 18 1 097 917 233 1 359 535 012 260 717 780 36 55,4 20,4 May 18 1 097 917 233 1 311 627 727 213 710 494 36 55,6 19,6 Jun 18 1 097 917 233 1 262 563 508 164 646 275 36 55,6 18,8 Jul 18 1 097 917 233 1 187 543 240 89 626 007 36 51,4 15,4 Aug 18 1 097 917 233 1 201 116 634 103 199 401 36 49,7 13,7 Sep 18 1 097 917 233 1 200 445 038 102 527 805 36 49,1 13,1 Oct 18 1 097 917 233 1 192 116 814 94 199 581 36 47,5 11,5 Nov 18 1 097 917 233 1 205 038 489 107 121 256 36 47,7 11,7 Dec 18 1 097 917 233 1 218 228 623 120 309 890 36 47,2 11,2 Jan 19 1 097 917 233 1 235 361 484 137 444 251 36 47,6 11,6 Feb 19 1 097 917 233 1 215 660 433 117 743 201 36 46,4 10,4 Mar 19 1 097 917 233 1 193 232 410 95 315 177 36 45,0 9,0 Apr 19 1 097 917 233 1 184 020 500 86 103 267 36 44,2 8,2 May 19 1 097 917 233 1 169 528 771 71 611 538 36 43,2 7,2 Jun 19 1 097 917 233 1 170 492 885 72 575 652 36 42,7 6,7 Jul 19 1 097 917 233 1 134 805 081 36 887 848 36 41,1 5,1 Aug 19 1 097 917 233 1 128 044 557 31 127 324 36 40,7 4,7 Sep 19 1 097 917 233 1 124 696 639 26 779 407 36 40,4 4,4 Oct 19 1 097 917 233 1 115 717 805 17 800 572 36 40,0 4,0 Nov 19 1 097 917 233 1 105 816 062 7 898 829 36 39,8 3,8 Dec 19 1 097 917 233 1 092 105 984 – 5 811 249 36 39,4 3,4 Jan 20 1 097 917 233 1 093 377 536 – 4 539 697 36 39,6 3,6 Feb 20 1 097 917 233 1 087 208 111 – 10 709 122 36 39,4 3,4 Mar 20 1 097 917 233 1 092 112 830 – 5 804 403 36 39,6 3,6 Apr 20 1 097 917 233 1 078 736 768 – 19 180 465 36 39,6 3,6 May 20 1 097 917 233 1 078 741 657 – 19 175 576 36 39,6 3,6 Jun 20 1 097 917 233 1 071 919 812 – 25 997 421 36 39,8 3,8 Jul 20 1 097 917 233 1 066 780 010 – 31 137 223 36 39,5 3,5 Aug 20 1 097 917 233 1 065 643 400 – 32 273 833 36 39,7 3,7 Sep 20 1 097 917 233 1 063 898 673 – 34 018 560 36 39,7 3,7 Oct 20 1 097 917 233 1 061 558 949 – 36 358 284 36 39,5 3,5 Nov 20 1 097 917 233 1 058 591 804 – 39 325 429 36 39,4 3,4 Dec 20 1 097 917 233 1 040 916 290 – 57 000 943 36 39,3 3,3 4.3.2 Stoping – Summary of EAC and Schedule at Completion Table 33: Summary of OCD EAC and SAC Stoping Analysis Jan 18 Feb 18 Mar 18 Apr 18 May 18 Jun 18 Jul 18 Aug 18 Sep 18 Oct 18 Nov 18 Dec 18 Jan 19 Feb 19 Mar 19 Apr 19 May 19 Jun 19 Jul 19 Aug 19 Sep 19 Oct 19 Nov 19 Dec 19 Jan 20 Feb 20 Mar 20 Apr 20 May 20 Jun 20 Jul 20 Aug 20 Sep 20 Oct 20 Nov 20 Dec 20 Total budget 1 577 714 609 EVM Cost prediction Estimate at Completion 2 028 789 025 1 630 236 906 1 887 861 505 1 643 889 493 1 834 316 354 1 618 071 087 1 897 719 926 1 637 045 192 1 657 380 160 1 838 371 212 1 677 408 185 1 660 444 723 1 679 454 550 1 685 222 292 1 708 228 970 1 721 021 027 1 724 015 218 1 734 243 091 1 722 178 946 1 713 502 625 1 700 482 012 1 685 880 447 1 688 088 336 1 685 225 705 1 682 682 899 1 674 786 653 1 676 930 743 1 682 517 308 1 683 527 833 1 684 351 889 1 696 259 819 1 702 639 432 1 703 608 634 1 709 168 877 1 725 085 425 1 727 940 885 Var EAC vs Budget 451 074 216 52 522 197 410 146 890 65 873 784 58 601 725 40 358 448 20 005 318 59 330 583 59 815 552 60 456 623 100 130 548 82 730 114 101 739 941 117 507 684 128 514 361 145 306 418 146 300 607 156 528 482 144 464 237 135 788 217 122 777 403 116 165 838 120 374 727 107 512 096 104 966 506 97 072 045 99 216 135 104 802 700 108 813 224 106 637 291 118 545 210 124 924 823 126 091 025 131 481 268 148 370 816 180 225 945 Total period 36 36 36 36 36 36 36 36 36 36 36 36 36 36 36 36 36 36 36 36 36 36 36 36 36 36 36 36 36 36 36 36 36 36 36 36 EVM Schedule prediction Schedule at Completio n 42,3 34,5 42,8 36,4 36,1 35,8 34,9 35,0 34,9 34,3 36,0 34,6 34,2 34,3 34,6 34,7 34,7 34,6 34,7 34,8 34,5 34,6 34,8 34,7 34,9 34,9 36,2 35,4 35,4 35,3 35,3 35,5 35,3 35,2 35,5 35,5 Var SAC vs period 6,3 -1,5 6,8 0,4 0,1 -0,1 -1,1 -1,0 -1,1 -1,7 -1,0 -1,4 -1,8 -1,7 -1,4 -1,3 -1,3 -1,2 -1,3 -1,5 -1,5 -1,4 -1,2 -1,5 -1,1 -1,1 -0,8 -0,6 -0,6 -0,7 -0,7 -0,5 -0,7 -0,8 -0,5 -0,5 4.4 POSSIBLE FUTURE EXTENSION OF RESEARCH While conducting this study, the following areas of concern became evident: ? Face advance. The face advance is the stoping panel that is mined to extract the reef. As noticed in Table 33, the average face advance achievement was 8.7 m per month. The face advance two decades ago was almost three times of this performance. A study determining the factors that caused this lower plan and achievements may be highly beneficial to challenge these factors. Table 34: Face advance average per year vs actual (A-Mine) Graph 21: Face advance average per year vs actual (A-Mine) ? Mine Call Factor (MCF). The MCF is the percentage of gold that is lost due to various reasons. The geologist determines the gold grade per ton utilising history and exploration drilling programs. Once mining is done in these areas, it is found that the gold is not as determined. This factor will implicate the amount of gold not recovered. Table 35: MCF 5 year average plans vs actual (A-Mine) An average of -1.8 % less on the MCF than planned may not look like a lot. But when looking at the number of mined tonnes, this small percentage adds up to millions lost in revenue. Graph 22: MCF 5 year average plans vs actual (A-Mine) The negative impact can be researched if the study is extended, and alternative management solutions could be proposed. 4.5 LESSONS LEARNED A general assumption made is that a small percentage do not matter. In the case of the stoping analysis, the costs are overspent with only 11.1%. This percentage does not sound like much, but in this case, it was R 175,526,329. When percentages are discussed, the context in which they are mentioned and their impact need to be understood. 4.6 CONCLUSION This study was based only on the summarised OCD and stoping parameters over three years. A better value will be created if the survey can be done in detail to demonstrate all the problem's key value destroyers and value contributors. Areas of concern are easily identifiable when looking at the analyses. Still, when it can be done in more detail, the areas per responsible Manager, Mine Overseer or Shift Overseer could be analysed. An underperforming supervisor's progress is now hidden within the better performance of their colleagues. 5 CHAPTER 5 – CONCLUSION AND RECOMMENDATION 5.1 INTRODUCTION The objectives for this study were: ? to demonstrate the effectiveness of using EVM on operational cost activities; ? create awareness on how EVM can assist in tracking the program better and saving millions of Rands within the operational cost areas; ? to demonstrate how production can be effectively managed (cost vs progress) by using more extended durations; and ? to show the simplicity in using a dashboard (CPR & SPR) by offering the ease of reporting and visibility of variance results. The benefit of this contribution has been identifying what improvement using EVM on working costs can add to the overall strategy of making a mine more successful and sustainable. The benefits for the mine, which were demonstrated through this research by using EVM, would include a(n): ? decrease its operating cost expenditure (increase efficiencies); ? increase its production rates due to better focus on the bigger picture; and ? increase profitability. This study's findings demonstrated the benefits of using EVM, which can give the mine a competitive advantage in the mining industry. Earned Value Management must still

find its place in the mining operation cost discipline. Using EVM will make a great mine an even better one. 5.2 FINDINGS FROM DATA This study was only focused on the OCD, stoping planned, and actual performances. The raw data received gave the following incremental values: Ongoing-Capital-Development ? Planned metres – 26,003 metres ? Planned cost – R 1,097,917,233 ? Actual metres achieved – 23,833 metres ? Actual expenditure achieved – R 972,389,012 From the initial data, it is clear that the OCD underperformed with 2,170 metres over the three years, and the total cost was underspent with R 125,528,221. The data did not show if the value of money was achieved or how far the OCD have fallen behind. The early indication was the production was 9.1% below target, and the cost was 12.9% underspent. This cost was a positive indication. Stoping ? Planned m2 – 371,841 m2 ? Planned cost – R 1,577,714,609 ? Actual m2 achieved – 377,285 m2 ? Actual expenditure achieved – R 1,753,240,938 From the original data, over the three years, the stoping over-performed with 5,444 m2 and the total cost was overspent with R 175,526,329. These achievements do not indicate value for money or how far the stoping has overachieved the plan. Doing more work justified more costs but is the additional cost in line with the additional stoping achieved? The early indication showed that the production had achieved 1.4 % more stoping, but the cost was overspent by 11.1%. An early challenge could be noticed with the large discrepancy between the work achieved and the cost percentage overrun. 5.3 FINDINGS FROM THE OBSERVED STUDY An Excel database with the abovementioned data was compiled to allow for cumulative values and EVM calculations. This calculation could determine the PV, EV, AC, CV, SV, CPR and SPR at any given month over the three-year window. Using the CPR and SPR, a forecast of the likely over-or under-expenditure could be determined. With the SPR, a forecast on the schedule deviation could be calculated. The final EVM analysis for OCD was as follows: PV: R 1,097,917,233 EV: R 1,006,302,402 AC: R 972,389,012 SV:- R 91,614,781 CV: R 33,913,430 Graph 23: OCD EAC & SAC Analysis This study determined and demonstrated with EVM the forecasting ability of the cost and schedule outcome by using the CPR and SPR. The progress on areas can be seen in Graph 23 and Graph 24 on how the changes during the duration took place. This information will be compelling if it can be available for proactive management to take place. The final EVM analysis for the stoping was as follows: PV: R 1,577,714,609 EV: R 1,600,815,394 AC: R 1,753,240,938 SV: R 23,100,785 CV:- R 152,425,544 Graph 24: Stoping EAC & SAC Analysis 5.4 PROPOSED STRATEGY It is proposed that the mine seek its poorest-performing OCD and stoping section and do an EVM trial on them. Budgets for the production and cost targets to be achieved over a minimum of a two-year window should be compiled. The benefits will be seen within the first six months, and the rest of the OCD and stoping production areas can be adapted in the new budget cycle to comply with the EVM methodology. If the end-users (Mine- overseers) can see the bigger picture better and the consequences of their performance during the early stages, they will engage in better pro-active interventions to ensure the end target will be met. Early detection of variance will ensure that early corrective action is taken, hence providing the program and cost not to deviate and cause unnecessary loss of production and loss of revenue. 5.5 LIMITATIONS TO THE STUDY This study was done only using the summarised available information of the OCD and stoping areas over three years. The research intends to determine and demonstrate if and how EVM can add value to the abovementioned areas of concern. Although the study has reached its goal, a lower level of detail would have highlighted the areas that cause the organisation not to create ultimate value. 5.6 FUTURE RESEARCH STUDIES The future value-adding research that should be done is: ? South African remaining gold – With the highest recorded annual gold production of 619.2 tonnes during 1993 and a mere 90 tonnes being produced during 2020, 65 the question must be asked: Why? Has South Africa reached its record productions levels, or have our mines become inefficient producers of gold? ? Face advance – The face advance is the distance a gold-bearing stope is mined and measured in metres. o Benchmarking against production levels of the period between 1980 and 2000 would answer if our gold has depleted, o or if the labour force has lost its production and efficiency ability. ? Looking at what the effect of the current salary structures is on productivity. High salaries with low incentives (bonuses) if targets are met vs low salaries with high incentives (bonuses) if production targets are achieved. 5.7 CHAPTER SUMMARY This study has proven that millions of Rands can be saved by implementing EVM on the operational cost areas of the mine. Furthermore, by using this tool to determine the outcome of the schedule based on its current performance, the potential loss can be calculated or mitigated. The commitment of all mine employees is evident, but to this day, any additional tool that can assist in better management must be embraced. The main benefit of implementing EVM is that the scope, time, and money are entirely integrated, and if one of these areas moves from the pre-determined line, it becomes apparent. 6 REFERENCES

AACEI, 2021. Cost Engineering. [Online] Available at: https://web.aacei.org/about-aace/what-is-cost-engineering [Accessed 11 September 2021]. Accram, A., 2021. Mining sector contributes R400 billion to GDP in 2020: Minerals Council. [Online] Available at: https://www.sabcnews.com/sabcnews/mining-sector-contributes-r400- billion-to-gdp-in-2020-minerals-council/ [Accessed 11 September 2021]. Alsbouri, A., 2020. Cross-sectional study Vs. Longitudinal study (research). [Online] Available at: https://www.enviroaccount.com/single-post/2018/02/08/cross-sectional- study-vs-longitudinal-study-research [Accessed 27 September 2021]. Anbari, F. T., 2011. Advances in earned schedule and earned value management. [Online] Available at: https://www.pmi.org/learning/library/advances-earned-schedule-value-management-6217 [Accessed 22 November 2021]. Artifacts, M., 2021. South African Mines. [Online] Available at: http://www.miningartifacts.org/South-African-Mines.html [Accessed 23 September 2021]. Buthelezi, L., 2021. Mantashe outlines plan to get mining to contribute at least 12% of SA's GDP. [Online] Available at: https://www.news24.com/fin24/economy/south-africa/mantashe-outlines- plan-to-get-mining-to-contribute-at-least-12-of-sas-gdp-20210527 [Accessed 15 September 2021]. CEIC, 2021. South Africa Gold Production. [Online] Available at: https://www.ceicdata.com/en/indicator/south-africa/gold-production [Accessed 17 August 2021]. Club, O. C., 2021. One Rand 2020, Coin from South Africa - detailed information. [Online] Available at: https://onlinecoin.club/Coins/Country/South_Africa/One_Rand_2020/ [Accessed 02 September 2021]. Consulting, T. G., 2021. THE HISTORY OF EARNED VALUE MANAGEMENT. [Online] Available at: https://tgcsc.com/the-history-of-earned-value-management [Accessed 19 September 2021]. Cornish, L., 2015. SEFATENG CHROME MINE. [Online] Available at: https://www.miningreview.com/tag/sefateng-chrome-mine/ [Accessed 07 October 2021]. Dreamstime, 2021. Conveyor mining stock photos. [Online] Available at: https://www.dreamstime.com/royalty-free-stock-photo-conveyor-belt- crusher-image107946259_ [Accessed 11 October 2021]. Eby, K., 2021. The Triple Constraint: The Project Management Triangle of Scope, Time, and Cost. [Online] Available at: https://www.smartsheet.com/triple-constraint-triangle-theory [Accessed 11 September 2021]. Economics, T., 2021. Gold. [Online] Available at: https://tradingeconomics.com/commodity/gold [Accessed 17 October 2021]. Encyclopaedia, T. E. o., 2021. stoping. [Online] Available at: https://www.britannica.com/technology/stoping [Accessed 14 October 2021]. Fostel, C., 2011. The value of earned value management. [Online] Available at: https://www.pmi.org/learning/library/earned-value- management-systems- analysis-8026 [Accessed 14 September 2021]. Garside, 2020. Revenue distribution of mineral mining in South Africa in 2020, by commodity. [Online] Available at: https://www.statista.com/statistics/1014905/south-africa-mineral-commodity-revenue/ [Accessed 28 August 2021]. Gold(A), H., 2021. Mineral Resources and Mineral Reserves.

[Online] Available at: https://www.harmony.co.za/21/ [Accessed 14 October 2021]. Gold(B), H., 2021. Mineral Resources and Mineral Reserves. [Online] Available at: https://www.har.co.za/21/ [Accessed 19 October 2021]. Goldfields-Southdeep, 2021. Overview. [Online] Available at: https://www.goldfields-southdeep.co.za/about-us/about-south-deep/overview [Accessed 17 October 2021]. Gold, H., 2021. Mponeng. [Online] Available at: https://www.harmony.co.za/business/sa/mponeng [Accessed 11 September 2021]. GoldHub, 2021. Gold mine production. [Online] Available at: https://www.gold.org/goldhub/data/historical-mine-production [Accessed 15 September 2021]. Guide, P., 2021. PMBOK® Guide. [Online] Available at: https://www.pmi.org/pmbok-guide-standards/foundational/PMBOK [Accessed 18 September 2021]. Guide, T. S. A., 2021. The Great Trek. [Online] Available at: https://www.thesouthafricaguide.com/famous-south-africans-and- history/south-african-history-history-of-south-africa-the-great-trek/ [Accessed 09 September 2021]. Harper, J., 2020. How much gold is there left to mine in the world?. [Online] Available at: https://www.bbc.com/news/business-54230737 [Accessed 14 September 2021]. History, S. A., 2018. Discovery of the Gold in 1884. [Online] Available at: https://www.sahistory.org.za/article/discovery-gold-1884 [Accessed 17 September 2021]. International, A., 2017. What is Earned Value Management and Why is it Important?. [Online] Available at: https://apmg-international.com/article/what-earned-value-management- and-why-it-important [Accessed 27 September 2021]. IQ, A. M., 2019. Gold Mining in South Africa. [Online] Available at: https://www.projectsiq.co.za/gold-mining-in-south-africa.htm [Accessed 04 September 2021]. Johnson, D., 2021. What is Data Analysis?. [Online] Available at: https://www.guru99.com/what-is-data-analysis.html#:~:text=Data analysis is defined as,based upon the data analysis. [Accessed 05 October 2021]. Lanel, A., 2015. Tough choices facing the South African mining industry. [Online] Available at: http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S2225- 62532015000600005 [Accessed 7 September 2021]. M.Sguazzin, 2021. Number of people employed by South Africa's mining industry in 2020 by commodity. [Online] Available at: https://www.statista.com/statistics/241420/south-african-mining-key-facts/ [Accessed 12 September 2021]. Martin, J., 2021. Tailings Facility Design. [Online] Available at: https://www.srk.com/en/projects/laner-iron-ore-mine-tailings [Accessed 11 October 2021]. Mining, W. W., 2021. WITWATERSRAND BASIN PROJECT. [Online] Available at: https://westwitsmining.com/witwatersrand-basin-project/ [Accessed 27 August 2021]. OANDA, 2020. South African Rand. [Online] Available at: https://www1.oanda.com/currency/iso-currency-codes/ZAR [Accessed 11 September 2021]. Pinkasovitch, A., 2021. An Introduction to Capital Budgeting. [Online] Available at: https://www.investopedia.com/articles/financial-theory/11/corporate- project-valuation-methods.asp [Accessed 08 September 2021]. Point, J. T., 2021. Data Mining Implementation Process. [Online] Available at: https://www.javatpoint.com/implementation-process-of-data-mining [Accessed 01 October 2021]. Reeder, S., 2020. Earned Value Management Formulas and Calculations. [Online] Available at: https://www.schedulereader.com/blog/earned-value-management- formulas-and-calculations [Accessed 28 September 2021]. Rosato, B., 2018. Estimate at Completion (Earned Value Analysis). [Online] Available at: https://www.projectengineer.net/estimate-at-completion-earned-value- analysis/ [Accessed 14 September 2021]. Services, M. P., 2020. The Origins and History of Earned Value Management. [Online] Available at: chrome- extension://efaidnbmnnnibpcajpcglclefindmkaj/viewer.html?pdfurl=https://mosaicprojects.com.au/PDF_Papers/P207_EVM_History.pdf&clen=473503&chunk=true [Accessed 15 September 2021]. StatsSA, 2017. Mining: A brief history. [Online] Available at: http://www.statssa.gov.za/wp-content/uploads/2017/04/Mining_pic2.png [Accessed 17 August 2021]. Stillwater, S., 2021. Sibanye-Stillwater Mineral Resources and Mineral Reserves 2020. [Online] Available at: https://www.sibanyestillwater.com/business/southern-africa/gold- operations/beatrix/ [Accessed 14 October 2021]. Thompson, K., 2017. The Steps of Quantitative Research. [Online] Available at: https://revisesociology.com/2017/11/28/the-steps-of-quantitative-research/ [Accessed 27 September 2021]. tools, A., 2021. What is flex budgeting. [Online] Available at: https://www.accountingtools.com/articles/how-does-flex-budgeting- work.html [Accessed 19 October 2021]. Viewpoint, 2021. MINE FEATURES. [Online] Available at: http://viewpointmining.com/index.php [Accessed 05 October 2021]. Wikipedia, 2021. List of countries by gold production. [Online] Available at: https://en.wikipedia.org/wiki/List_of_countries_by_gold_production [Accessed 15 September 2021]. Wondershare, 2021. Work Breakdown Structure (WBS) for Dummies: The Ultimate Guide. [Online] Available at: https://www.edrawmax.com/wbs/ [Accessed 19 September 2021]. 7 APPENDICES APPENDIX A Informed consent form APPENDIX B Ethics application approval APPENDIX C Title registration letter APPENDIX D Editing certificate APPENDIX E Student id APPENDIX F Turnitin Report 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 57 58 59 61 62 63 64 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56