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Strategic mine planning approach for determination of operational pushbacks using Datamine NPV Scheduler: case study of the Mashamba East open pit mine, Democratic Republic of Congo

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ABSTRACT: The Mashamba East open pit mine is a copper-cobalt operation located in the Democratic Republic of Congo, in the mineral-rich Katanga Province 10 km southeast of Kolwezi town. Previously owned by Gecamines (a state-owned mining company), Mashamba East pit was recently separated from the neighbouring Mashamba West deposit, which now belongs to a Chinese company (Sicomines). The challenges in the mine optimization and the pushback approach will be to take into account the presence of a waste dump on the south of the deposit, the small distance between the pit and the property limits to the east and west of the deposit, and finally, the presence of a tailings storage facility to the north of the pit,. Running the input data through Datamine NPV Scheduler showed that it is possible to design operational pushbacks to produce a well-balanced schedule and mining sequence. Mashamba East pit is located in a confined area, and this paper outlines the approach taken to achieve a viable mining sequence, taking into account the abovementioned restrictions. NPV Scheduler software will be used to optimize and determine pushbacks, while Minesight software will be used to design the ultimate pit and the operational pushbacks.

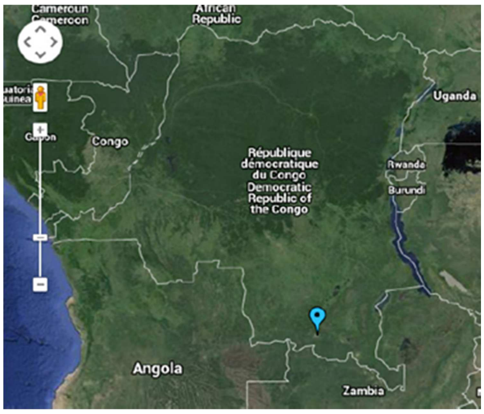
KEYWORDS: mine optimization, ultimate pit, long term open pit mine planning, Lersch-Grossman algorithm.

1 INTRODUCTION

International Modern strategic mine planning techniques are widely used in the industry to develop open pit mines and to predict returns on investment for both small-scale and large-scale open pit operations. Today it is possible for mine planners to run multiple simple or complex scenarios that satisfy corporate objectives using powerful computer software. The Mashamba East open pit mine has been planned based on a corporate target of 3.2 Mt of ore per year to be sent directly to the mill (the B4 mill) and approximately 30 Mt of waste material to at the waste dump to the south of the mine, using CAT 777F dump trucks and CAT6030FS front-end shovels. The pit area is constrained in the north by a tailing storage facility (TSF), to the south by the mine waste dump, on the east side by the property boundary, and on the west side, by the Mashamba West operation of Sicomines (a Chinese mining company). This paper discusses the steps, the design approach in terms of access location, and the planning strategy on how to develop the Mashamba East open pit mine, given these spatial constraints.

1.1 LOCATION

Mashamba open pit is located in the Kolwezi (Figure 1) area within the Central African Copperbelt in the Democratic Republic of Congo (DRC). The geological setting is summarized in Figure 2.



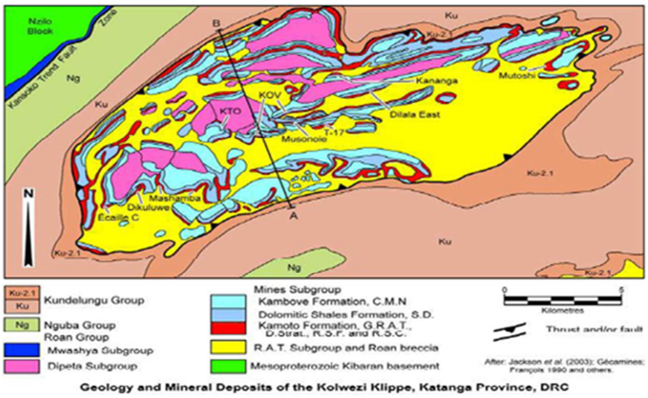


Fig1. Kolwezi town location *Fig2.Mashamba open pit geological setting*

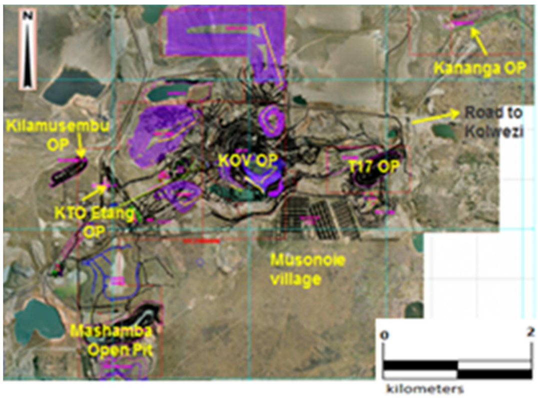


Fig3. Mashamba open pit mine location in the Katanga mining limited property

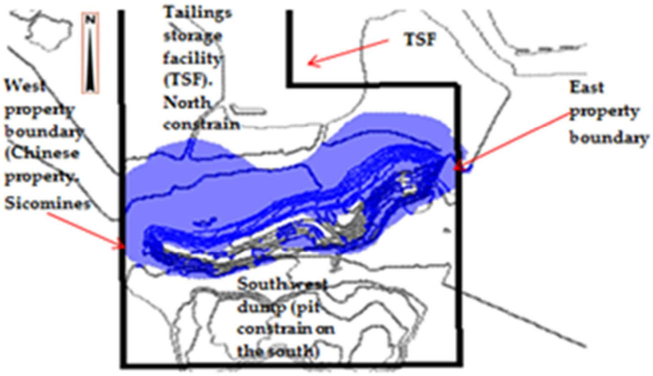


Fig4. Mashamba open pit mine (blue shaded) location and spatial constrains

1.2 HISTORICAL CONTEXT AND OWNERSHIP

Kamoto Copper Company SA (KCC) has owned the property and the associated the mining and exploitation rights since 2006. Katanga Mining Limited (KML) holds a 75% stake in KCC. La Generale des Carrieres et des Mines (GCM) and La Société Immobilière du Congo (SIMCO), state-owned mining companies in the DRC, own the other 25% of KCC. Table 1 summarizes the different permits that the company acquired in order to operate legally in the DRC.

Table 1. Kamoto Copper Company permits that include the Mashamba open pit mine.

Property	Exploitation permit number no.	Rights granted	Holder	Area of title	Valid until
Kamoto underground mine and Mashamba East open pit	PE525	Cu, Co and associated minerals	KCC	13 blocks, 11.04 km^2	03/04/2024 Renewable
T-17 open pit	PE11602	Cu, Co, nickel and gold	KCC	2 blocks, 1.698 km^2	03/04/2024 Renewable
Extension of Kananga	PE11601	Cu, Co, nickel and gold	KCC	1 block, 0.849 km^2	07/05/2022 Renewable
Property	Exploitation permit number no.	Rights granted	Holder	Area of title	Valid until
KOV open pit	PE4961	Cu, Co and associated minerals + use of surface	KCC	10 blocks, 8.49 km2	03/04/2024 Renewable
Tilwezembe open pit	PE4963	Cu, Co and associated minerals + use of surface	KCC	9 blocks, 7.64 km2	03/04/2024 Renewable
Kananga Mine	PE4960	Cu, Co and associated minerals + use of surface	KCC	13 blocks, 11.04 km2	03/04/2024 Renewable

2 METHODOLOGY

The Mashamba East open pit mine geological model was reviewed in the third quarter 2014 by AMEC consulting company, and reserves in the entire model are shown as per the summary in Table 2. The pit geotechnical area has been split into two zones: zone 1 to the north, which will be optimized with an overall slope angle of 40 degrees, and the south zone or zone 2, which will be optimized with an overall slope angle of 25 degrees (see sketch in Figure 5).

Table 2. Material in the block model inventory using NPV Scheduler

Material split in the block model	tons
Ore	56 ,203, 269
Waste	25, 752 ,558 ,961
Total	25, 808 ,762 ,184

The ore is classified into three main categories: INFOX or oxide copper material, INFMX or mixed copper material, and INFSUL or sulphide copper material. Oxide and mixed ore are processed by crushing, milling, flotation, and elecrowinning (EW), and sulphide material by crushing, milling, and roasting. A detailed ore and waste material inventory is given in Table 3.

Table 3. Detailed material split in the block model inventory using NPV Scheduler

Material split	Code	tons
INFOX	7	48, 719 ,243
INFMX	8	6 ,200 ,519
INFSUL	9	1 ,283 ,508
Waste	10	25 ,752 ,558 ,961

The geotechnical zones are shown in Figure 5.

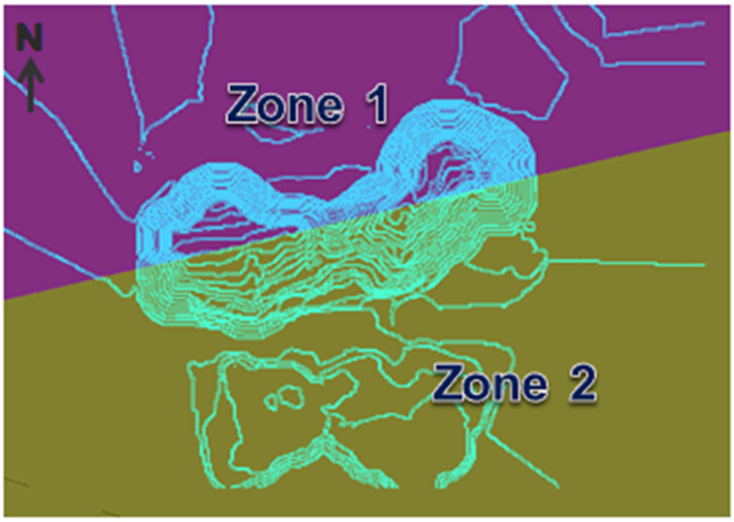


Fig5. Mashamba open pit mine geotechnical zones

This study was conducted under Glencore corporate office in June 2015, using the economic parameters in Tables 4–7.

Table 4. Copper price assumptions

Price		2013	2014	2015 (before copper price crash)	Units
	Copper	6 ,178	6 ,500	6 ,500	$/ton
		2.8	2.95	2.95	$/lb.
	Cobalt	25 ,062.00	24 ,250.82	24,250.82	$/ton
		11.37	11	11	$/lb.

Table 5. Mining costs applied to waste, oxide, mixed, and sulphide materials

Waste, oxide, mixed, and sulphide material		2013	2014	2015	Units
	Base	3.15	3.538	4.06	$/ton mined
	Reference	1,450	1,450	1,450	
	Incremental below reference using CAT 793 trucks	0.0273	0.0273	0.0273	$/ton mined
	Incremental below reference using CAT 777 trucks	0.0271	0.0271	0.0271	$/ton mined

Table 6. Processing costs applied to waste, oxide, and mixed materials.

Oxide and mixed mill concentrator	2013	2014	2015	Units
Processing cost	17	18.75	18.97	$/ton processed
SX-EW	0.54	0.27	0.274	$/saleable copper
Copper mill recovery (TCU KTC)	71.92	74.24	74.24	%
Cobalt mill recovery (TCO KTC)	70.32	43.84	43.84	%
TCU SX-EW recovery	87.82	85.5	85.5	%
TCO SX-EW recovery	51.79	30	30	%

Table 7. Processing costs applied to sulphide materials

Sulphide mill concentrator	2013	2014	2015	Units
Processing cost	7	7.24	7.24	$/ton processed
Roaster and SX-EW	0.36	0.18	0.18	$/saleable copper
Copper mill recovery (TCU KTC)	88	90	90	%
Cobalt mill recovery (TCO KTC)	79.1	65	65	%
TCU SX-EW recovery	83.82	87.4	87.4	%
TCO SX-EW recovery	49.45	30	30	%

The methodology used for the study is summarized in Figure 6, using the abovementioned geotechnical and technical parameters.

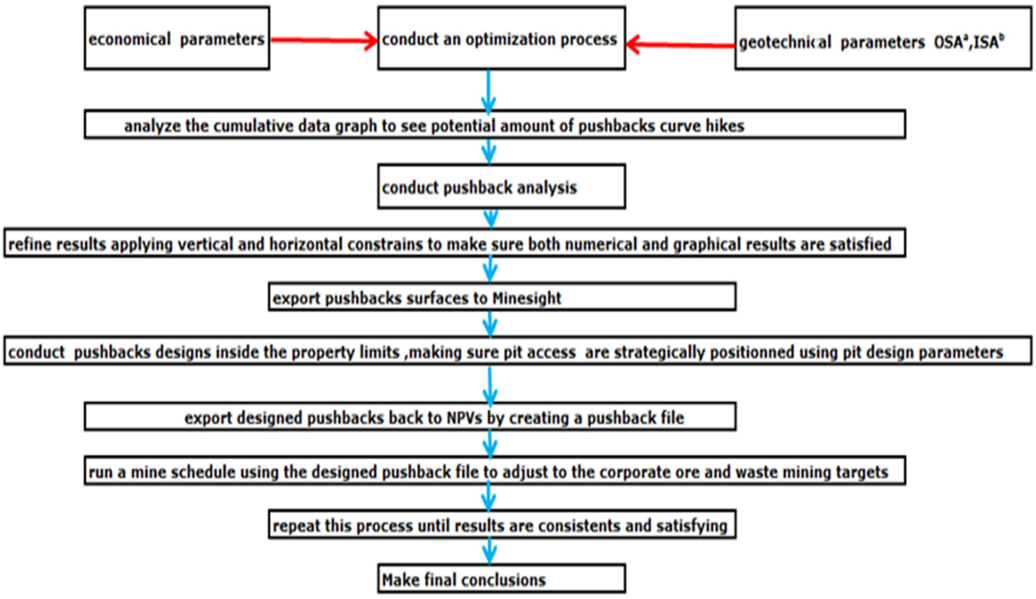


Fig6. Mashamba open pit overall strategic methodology

2.1 The Mashamba East Open Pit Mine Optimization Approach

Based on the input data and various constrains, (including the property boundary limits as per Figure 4, an optimization process was run which resulted in the following outputs.

2.2 Ultimate Pit Limits

Ultimate pit limits are shown in Figure 7, and the results are summarized in Table 8.

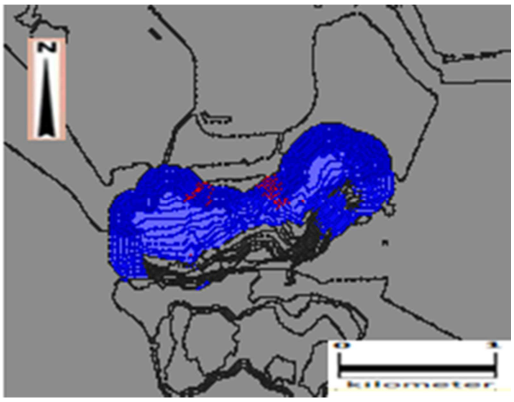


Fig7. Mashamba ultimate pits (NPV output surface)

Table 8. Ultimate pit (Pit78) ore and waste quantities where the revenue factor is 100%

Phase pit n°.	NPV(t)	Worst case NPV(t)	Total material(t)	Ore(t)	Waste(t)
Pit 72 (94)	669, 723, 070	657, 256, 811	127 ,789, 503	17 ,500, 715	110 ,288 ,788
Pit 73 (95)	669, 775, 058	657, 296, 697	127, 853 ,369	17, 510, 615	110 ,342, 754
Pit 74 (96)	671, 561 ,100	658, 760, 846	129, 837 ,747	17 ,703, 390	112, 134, 357
Pit 75 (97)	671, 670, 580	658, 853, 180	129, 945, 547	17, 711, 640	112, 233, 907
Pit 76 (98)	672, 398 ,691	659 ,444, 206	130,856, 347	17 ,809, 540	113, 046, 807
Pit 77 (99)	673, 717, 969	660, 430, 551	132, 739, 855	17 ,976 ,740	114 ,763 ,115
Pit 78 (100)	673, 878, 780	660, 524 ,659	133, 054, 708	18 ,017, 165	115, 037, 543

The cumulative graph of the pit optimization is shown in Figure 8.

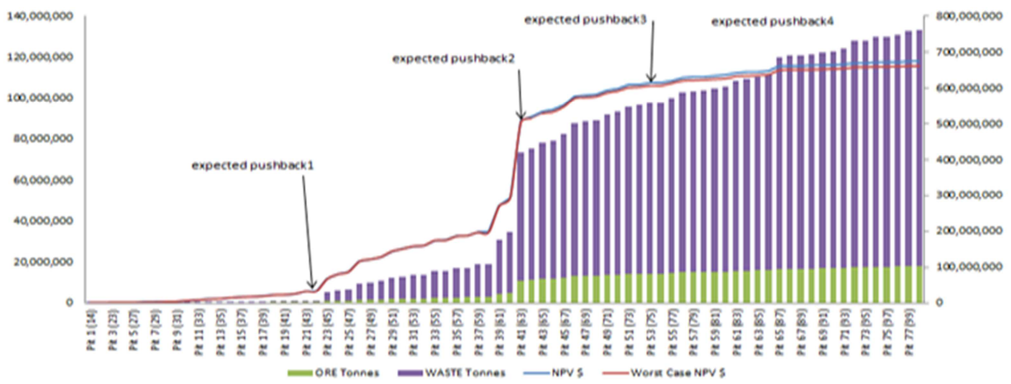


Fig8. Mashamba ultimate pit cumulative graphs and expected pushbacks

2.3 Pushback Analysis (the Challenge in Applying the Strategic Approach)

Based on the graph in Figure 8, there are some sharp hikes on pit 23, pit 42, pit 53, and pit 77, which is almost the ultimate pit limit size. This indicates that there are likely to be four or five pushbacks. At this stage, the number of pushbacks is speculative and the data has to be run through the NPV Scheduler pushback analysis tool for validation. Note that at this level of analysis, pit access and the ramp system are not yet incorporated.

- ***Scenario 1– Unconstrained (Sequence inside Property Limits)***

Figure 9 illustrates the pushback sequence with no size constraints applied.

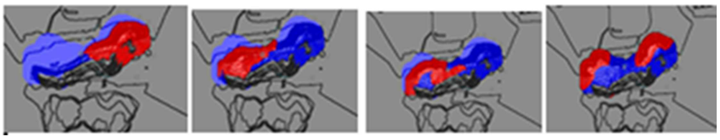


Fig9. Mashamba pushback sequence, without size constraints (from pushback 1 to 4, left to right)

Figure 9 shows that pushback 1 leaves a small amount of material that is later mined in pushback 4; this also shows that pushback 3 tends to be between (overlap) the East pit and the West pit. Although the tonnages generated are practical (see Table 9), the graphical sequence has to be adjusted using horizontal constraints polygons to ensure the physical practicality of the pit design.

Table 9. Pushback table (constraint-free scenario)

Pushback n°	Tons
1	29 ,756 ,485
2	34, 398 ,144
3	20, 500, 145
4	48 ,399, 934
Total	133, 054 ,708

- ***Scenario 2 –Some Polygon Constraints Applied Inside Property Limits***

For scenario 2, some polygon constraints were applied iteratively in the x, y directions to adjust the pushback sizes in order to achieve a practical mining sequence.

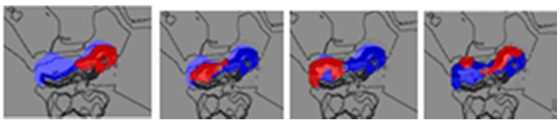


Fig10. Mashamba pushback sequence using iterative polygons and size constraints inside the property limits

Figure 10 shows that (from left to right) pushbacks 1, 2, and 3 have been adjusted to an appropriate size (remembering the ore and waste targets stated previously) but pushback 4 still leaves residual material to the west of the pit that needs to be incorporated in a practical mineable pushback. “Practical” also takes into account the need to minimize fleet or shovel relocations around the pit to avoid availability issues that impact production in general.

Table 10. Pushback table (constrained scenario)

Pushback no.	Tons
1	29, 756 ,485
2	34 ,398, 144
3	35 ,563, 204
4	33, 336 ,875
Total	133, 054 ,708

- ***Scenario 3 –Constrained Sequence inside Property Limits***

The last scenario (Figure 11) is a result of a combination of multiple other iterations to achieve an almost homogenous material distribution within all four pushbacks:

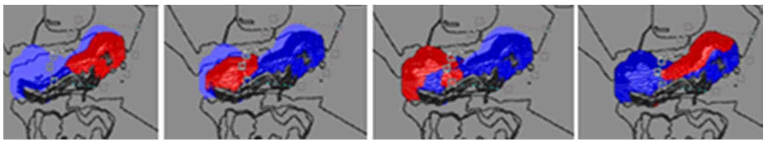


Fig11. Mashamba pushbacks – final sequence inside the property limits

Table 11. Pushback table (final scenario: graphical and numerical results are satisfactory)

Pushback no.	Tons
1	29, 756, 485
2	34 ,593, 658
3	38, 201, 702
4	30, 502, 863
Total	133 ,054, 708

As mentioned previously, the pushback configuration does not contain access and ramping systems. Before dealing briefly with pit design, a mining schedule has to be produced that will tell us the life of mine and how the 3.2 Mt of ore and 30 Mt of waste material per year will be achieved.

2.4 Mining Schedule

To achieve material targets, the following schedule was generated (Table 12 and Figure 12).

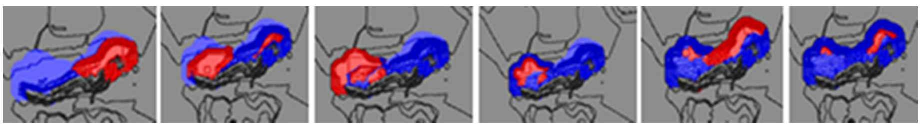


Fig12. Mashamba development sequence per year (from left to right)

Table 12. Mining schedule for Mashamba East pit

Year	Rock tons	NPV $	INFOX tons	INFMX tons	INFSUL tons	ORE tons
1	27, 906, 285	114 ,965, 021	3, 100, 273			3 ,100 ,273
2	32, 840, 258	91 ,648, 648	1, 668 ,700	628 ,023	803, 732	3, 100, 455
3	29, 480, 902	56, 104, 674	1 ,342, 605	1, 401, 301	357, 500	3 ,101 ,406
4	10, 964 ,800	114, 043, 905	2 ,118 ,875	979, 550		3 ,098 ,425
5	27, 977, 263	41 ,755, 960	3, 099 ,531			3, 099, 531
6	3, 885, 200	68 ,569, 149	2 ,517 ,075			2 ,517 ,075
Total	133 ,054 ,708	487 ,087 ,357	13, 847, 059	3 ,008, 874	1 ,161 ,232	18, 017, 165

Now that both graphical and numerical schedule achievability have been attained, we can introduce the access and ramping system.

After designing each pushback separately, including ramps, using Minesight, we superimposed each pushback surface to create a **pushback file** in the scheduler. Several schedules were run, and the results for the most satisfactory are summarized in Table 13:

Table 13. Mining-adjusted schedule for Mashamba East pit (ramping system included)

Year	Rock (tons)	NPV($)	INFOX (tons)	INFMX(tons)	INFSUL(tons)	ORE (tons)
1	40 ,360 ,089	55 ,229 ,078	3 ,251, 369			3, 251, 369
2	37 ,547, 912	79 ,682, 909	2, 313, 168	207, 829	727 ,953	3 ,248 ,950
3	29 ,192 ,906	67 ,493, 972	1 ,344 ,503	1 ,584, 275	321, 272	3, 250, 050
4	25, 881 ,614	77, 930, 111	1, 977, 410	1, 159, 021	113 ,284	3 ,249, 715
5	26, 846, 028	51, 788 ,898	3 ,251, 760			3 ,251 ,760
6	1, 801, 800	27, 087 ,588	1 ,033, 175			1,033, 175
Total	161, 630 ,348	359 ,212, 556	13, 171, 384	2 ,951 ,124	1 ,162 ,508	17 ,285, 019

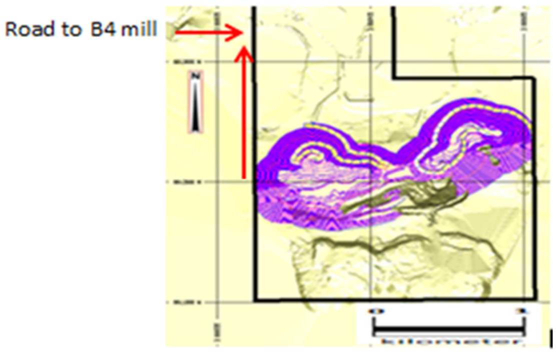


Fig13. Mashamba East final pit with ramping system and access included

3 Findings And Discussion

Adding a ramping system using 30 m wide ramps to access the pit from the north seems to be a better idea to avoid crossing the property boundaries by expanding the pit on the east and west sides, although it would have been beneficial to have an access at the west of the pit so as to provide direct access to the road to B4 mill. Also, this helps to minimize switchbacks and thus minimize the pit size. Addition of the ramping system increased the total material mined by almost 20%, but this can be reduced by refining the pit design to minimize waste material. Total material mined in year 4 shows a sharp drop on the original schedule with no ramp, but it is corrected (smoothed) with the additional material that is included by adjusting the schedule with the ramping system, and this has the advantage of maintaining a fairly homogeneous fleet size for the entire life of the mine, which avoids underutilization of equipment (see Figure 14). The NPV is very aggressive on year 1 of the original schedule ($114.9 million) but seems to follow a realistic and well-distributed trend along the life of the mine after adding ramps in the adjusted schedule. Although the highest NPV occurs at year 2 ($79 million) of the adjusted schedule, it is only in the first one-third (early returns on investment are guaranteed) of the entire life of the mine and seems to carry on until year 4 before starting to drop (see Figure 15).

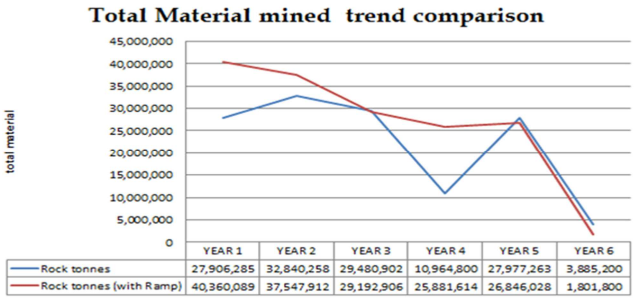


Fig14. Total material mined trends

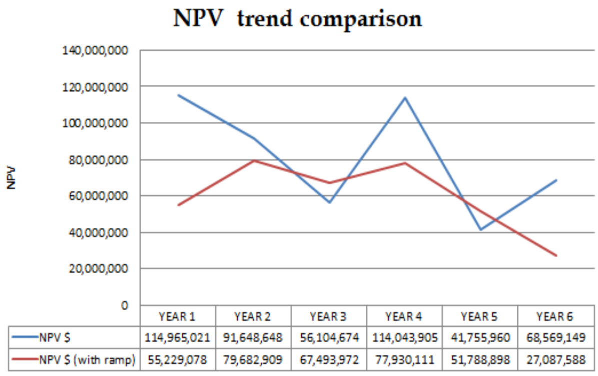


Fig15. NPV trend comparison

4 CONCLUSION

Mine planning, as it is conducted in the modern industry, seems to follow a generic methodology and pattern, but every mine is a different case. This study has demonstrated the great potential for generating a consistent schedule and life of mine results, by the application of a pushback file (size-controlled) in addition to a ramping system.

We demonstrated how, based on a cumulative pit shell graph analysis, it is possible to determine a first estimate on the pushbacks to be used to control the size of a pit in a confined area and to develop it into a well-defined mining schedule. In this study, although the results were not attained in a single run, we highlighted the steps of a strategic mine planning approach (strategic both on graphical material distribution per pushback, and numerical approach in terms of targets to achieve) to resolve this specific case study. Mashamba East open pit mine was intended to be a satellite pit of the bigger KOV pit, and a multi-pit approach that takes into account the simultaneous development of the two mines will need to be conducted to compare the resulting mining sequence for stronger validation of the results. This will be discussed in further papers if the opportunity arises in the future.

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