Strategic Mine Planning Approach Applied to Large Scale Copper open Pit Mines by Comparing The Impact of three Different Bloc Models of the Same Deposit, On the Long Term Mine Plan

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***Abstract*—The Kamoto Oliveira Virgule (KOV) open pit mine is located at 300Km from Lubumbashi, second largest city of the Democratic Republic of the Congo, in the mineral rich province of the Lualaba (EX-Katanga province).KOV pit is located 10Km south of the Kolwezi town and it is essentially constituted of sedimental rock, in a major portion of the so called "Lambeau Geologique de Kolwezi", which is a part of the well-known copperbelt mineralization. In 2006, a joint venture of Glencore, Gecamines (the DRC State owned Company), and Simco, took over the open pit mine, which was previously owned by Gecamines, and formed the Kamoto Copper Company (KCC).KOV open pit mine is classified as a large scale open pit mine due to his dimensions (approximately 2.5km East-West and 3Km North-South).the mine has also a high strip ratio ranging from 8 to 10 in some areas. At his initial stage (Prefeasibility study), SRK released a bloc model which is still be used by the Kamoto Copper Company (KCC), but since the geology department addressed the issue about grade control model ore discrepancies, when comparing it to the SRK model, the management hired another contractor that constructed another bloc model. Internal adjustments using the grade control model data to better predict tonnes and grades have been also implemented but reported very poor results .since reserves have been officially reported to the market in 2014 to the TSX, the reserve report had to remain consistent with the 2014 report, despite that the issue has been fixed ,it still for a matter of interest to conduct a comparative analysis, to check on the impact of the other bloc model on the life of mine and the mine schedule .since we know by comparison that the other model (OBM) has a difference in its 3D distribution of ore and waste material. This paper will be focused on determining the impact on the life of mine and the mine schedule of the KOV pit with regards of those differences, between the bloc models.**

***Index Terms*: Mine planning, mine scheduling, mine optimization, life of mine, ultimate pit.**

I. INTRODUCTION

The Kamoto Oliveira Virgule (KOV) open pit mine is located at 300Km from Lubumbashi, second largest city of the Democratic Republic of the Congo, in the mineral rich province of the Lualaba (EX-Katanga province).KOV pit is located 10Km south of the Kolwezi town and it is essentially constituted of sedimental rock, in a major portion of the so called "Lambeau Geologique de Kolwezi", which is a part of the well-known copperbelt mineralization.



Fig 1. Kolwezi town Location in the DRCongo

In 2006, a joint venture of Glencore, Gecamines (the DRC State owned Company), and Simco, took over the open pit mine, which was previously owned by Gecamines, and formed the Kamoto Copper Company (KCC).

During the prefeasibility stage, the SRK consulting company had conducted an analysis and came up with a Bloc model of the KOV pit area using interpolation techniques based on a lithological approach. After conducting several monthly reconciliations between the SRK model and the grade control model (used by geologists for grade control purposes), the percentage in terms of variance between the two models were so different in some areas of the pit, that the issue was addressed to review the SRK model. Another consulting company was hired to construct another KOV bloc model using exploration drill holes and other available data.

Interpolation techniques using validated geostatistical method was applied targeting mineralized zones. Results were a little bit confusing, it then appeared that SRK (which still our reference model), overestimated ore in some areas, and underestimated ore in other areas. Since the company reported reserves to the market Toronto stock exchange (TSX), in 2014 using the SRK model, the reserves reporting had to be kept consistent for the following years, to get a clear view on what

was happening to the complexity of the KOV pit mineralization, the company had to hire a third Contractor that suggested that it was suitable to interpolate using both hard boundaries using lithology and mineralized areas to come up with a better prediction of the long term mine planning bloc model of the KOV pit area.

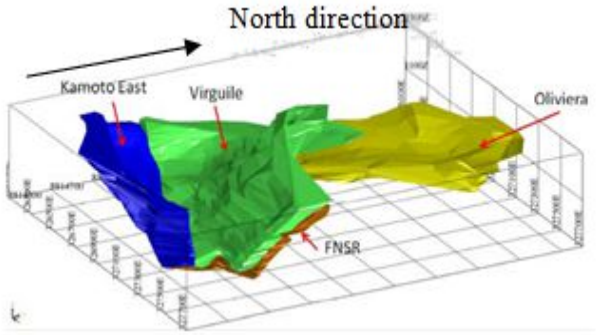


Fig 2. KOV Pit Oblique View Of the Resource Model.

Although discrepancies were not pretty much substantial, additional drill holes data were recommended to better define the deposit itself. Despite this long geological and geostatistical approach, the SRK model still the reliable model that the company is using, but the aim in this paper is to outline, the impact of the geological disparity observed in each one of the bloc model on the strategic mine plan of the KOV pit. One good thing to remember is that grades are consistent for all of the bloc models ,but the spatial distribution of the ore-waste materials are different, and this is impacting the mining optimization and the mining sequence or mining schedule. This is the purpose of our paper, as a matter of interest, to outline the impact of those disparities using a case study optimization and pushback analysis using KOV pit as an illustration.

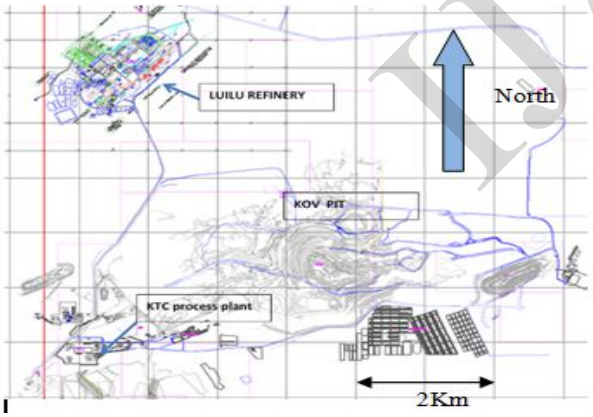


Fig 3. KOV pit Location and infrastructure.

II. METHODOLOGY

As mentioned precedently, the SRK bloc model is considered as the reference geological bloc model as it is used at KCC, and the second bloc model will be used to compare discrepancies and, eventually, the difference in the long term or strategic mine plan. In addition to those two models, we are also going to run an analysis using an hybrid bloc model (SRK model+Grade control Model), to finally come up with a global comparison in terms of impact on the respective life of mines.

We are going to conduct an open pit mine optimization to determine the ultimate pit extents in both cases and, also, we are going to conduct a pushback analysis, and determine a schedule or an extraction sequence to compare results in all cases. Note that, to compare apples with apples, we are going to use the NPV datamine scheduler software to run different optimization scenarios and schedules, using identical ultimate pit shell and identical pushback file, as well as the reference topography surface. Suggestions and comments will be made on our expected findings to finally come up with recommendations, or to address issues if any.

III. MINE OPTIMIZATION AND SCHEDULING

In the mining value chain, the main asset is the ore body, the deposit, or the mineralization that always comes up with adjacent waste material. The adjacent waste material is always associated with a strip ratio concept when the mine is required to be mined open pit. KOV pit is classified as a large scale open pit mine due to his dimensions and the length of his life of mine (LOM) estimated initially at 12 Years.

Open pit optimization is one of the first steps that require to be conducted before any further step is taken in strategic mine planning, the optimization process (using the NPV scheduler software),allows the planner, to see the final extents of the future mine when integrating economical, technical and geotechnical parameters. The ultimate pit is the results of the optimization process and allow to the user, to understand the potential problems or constrains that comes along with the result. The ultimate pit is generally a set of nested pits with regards of the commodity price sensitivity .the next step in the analysis that we are going to conduct is the pushback analysis.

Pushbacks are phases that we are going to take to get to the ultimate pit; generally, they are sets of nested pits and are ranging from the most valuable pit to the less valuable one. Finally comes the schedule or the mine plan itself, in this step, we are defining the length of the life of the mine and the optimal extraction sequence (we decide how long and which quantities and grades are going to be mined, especially where the material are going to be extracted) the scheduling part of the analysis defines how realistic (operational) will be your entire strategic approach. For the purpose of this paper, we are going to carry all the steps for the SRK bloc Model and the Other Bloc model (OBM), as well as the combined model.

A. Optimization and scheduling of SRK Bloc Model

We are going to enumerate economical, geotechnical, and technical parameters that will be used to run the optimization to avoid unnecessary comments for the purpose of this paper. Note that those parameters are exactly the same to be used for both bloc models.

- Commodity prices (copper and cobalt)
  The commodity prices used here are before the copper price crash in 2015.and prices are summarized in the table1.

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Table I. Commodity Prices.

	2013	2014	2015	Units
Copper	6,178	6,500	6,500	$/tonne
	2.8	2.95	2.95	$/lb.
Cobalt	25,062	24,250	24,250	$/tonne
	11.37	11	11	$/lb.

- Mining costs for ore and waste will be assumed to 4.06$/tonne mined and the same cost apply to the ore sent to the sulphide and oxide ore mill.
- Processing costs (Kamoto concentrator) is considered to be 18.75$/Tonne of ore processed and 0.27$/lb. salable copper for the electro winning and solvent extraction process.
- General and administration costs (0.24$/lb. of salable copper, sustaining capital for mining, concentrator and metallurgy are respectively: 0.53$/tonne mined, 0.22$/tonne processed and 0.004$/lb. of salable copper refined.
- Geotechnical parameters From North to south of KOV pit, the following geotechnical parameters have been applied as per Call &Nicholas recommendations.
- Note ISA (interamp slope angle) and OSA (overall slope angle) are the main Geotechnical parameters used to optimize.

Table II. Geotechnical Parameters Applied To KOV Pit.

Geotechnical zone	ISA	OSA
slope region1	31	26
slope region2	33	31
slope region3	34	32

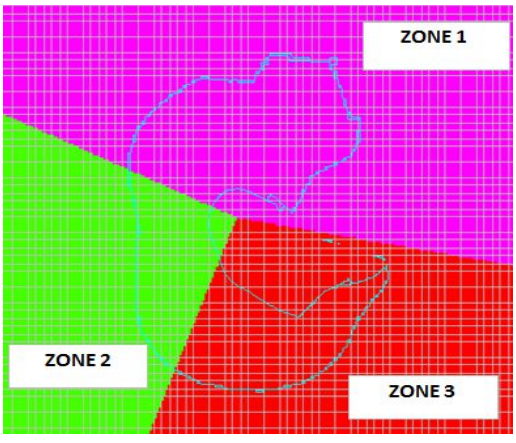


Fig 4. KOV Geotechnical Parameters.

B. Ultimate pit using SRK Model

After running the pit optimization process using the SRK model, the following results were recorded in the table3.

Table III. SRK Model Statistics

	Mass(tonnes)
ORE	248,056,600
WASTE	24,145,543,400
TOTAL	24,393,600,000

Table IV. SRK Economics model statistics

	Bloc count	Mass(tonnes)
ORE	32,004	223,854,400
WASTE	2,739,996	24,169,745,600
TOTAL	2,772,000	24,393,600,000
Strip Ratio	108	

Table V. SRK Ultimate pit statistics

	Bloc count	Mass(tonnes)
ORE	9,197	66,996,600
WASTE	46,058	419,247,400
TOTAL	55,255	486,244,000
Strip Ratio	6.26	

C. Ultimate pit using the Other Model (OBM)

After running the pit optimization process using the OBM model, the following results were recorded in the table 6.

Table VI. OBM MODEL statistics

	Mass(tonnes)
ORE	196,861,504
WASTE	24,196,739,011
TOTAL	24,393,600,529

Table VII. OBM Economics model statistics

	Bloc count	Mass(tonnes)
ORE	28,845	196,631,600
WASTE	2,743,155	24,196,968,400
TOTAL	2,772,000	24,393,600,000
Strip Ratio	123	

Table VIII. OBM Ultimate pit statistics

	Bloc count	Mass(tonnes)
ORE	8,851	61,868,400
WASTE	63,720	576,756,400
TOTAL	72,571	638,624,800
Strip Ratio	9.32	

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D. Ultimate pit using the Combined Model (SRK+Grade control model)

After running the pit optimization process using the combined model, the following results were recorded in the table 9.

Table IX. Combined MODEL Statistics

	Mass(tonnes)
ORE	53,448,388
WASTE	3,837,520,593
TOTAL	3,890,968,983

Table X. Combined Economics Model Statistics

	Bloc count	**Mass(tonnes)**
ORE	24,360	45,474,061
WASTE	1,760,390	3,845,494,838
TOTAL	1,784,750	3,890,968,899
Strip Ratio	84.56	

Table XI. Combined Ultimate pit statistics

	Bloc count	**Mass(tonnes)**
ORE	10,908	22,864,433
WASTE	207,402	454,748,392
TOTAL	218,310	477,612,824
Strip Ratio	19.89	

E. Mining schedules, results for SRK, OBM and Combined models.

- The resulting long term mine schedule using the SRK model is shown on table 12. (Increased values in ore and waste are due to additional ramps and pit access).

Table XII. Life of Mine and Mine schedule (SRK Model)

Year	Ore (tonnes)	Waste(tonnes)	Strip ratio
Year1	6,502,100	68,403,500	10.52
Year2	6,502,100	71,439,500	10.98
Year3	6,499,900	69,831,300	10.74
Year4	6,497,700	63,805,500	9.8
Year5	6,502,100	76,552,300	11.77
Year6	6,502,100	56,321,100	8.66
Year7	6,502,100	24,588,300	3.78
Year8	6,493,300	24,148,300	3.71
Year9	6,501,000	56,779,800	8.72
Year10	6,501,000	51,658,200	7.94
Year11	3,454,000	1,650,000	0.47
Total	68,457,400	565,177,800	8.25

- The resulting long term mine schedule using the OBM model is shown on table 13.

Table XIII. Life of Mine and Mine schedule (OBM Model)

Year	Ore (tonnes)	Waste(tonnes)	Strip ratio
Year1	6,504,300	86,300,500	13.26
Year2	6,501,000	96,145,500	14.79
Year3	6,499,900	78,877,700	12.1
Year4	6,498,800	71,438,400	10.9
Year5	6,496,600	69,183,400	10.6
Year6	6,506,500	38,980,700	5.9
Year7	6,495,500	44,359,700	6.82
Year8	6,501,000	39,045,600	6.0
Year9	6,496,600	45,229,800	6.96
Year10	3,331,900	2,220,900	0.66
Total	61,832,100	571,782,200	9.24

- The resulting long term mine schedule using the combined model is shown on table 14.

Table XIV. Life of Mine and Mine schedule (Combined Model)

Year	Ore (tonnes)	Waste(tonnes)	Strip ratio
Year1	6,436,536	28,127,000	4.52
Year2	6,433,690	58,609,100	9.29
Year3	57,76	-	-
Total	12,927,991	86,736,100	6.87

IV. FINDINGS AND COMMENTS

After running the three different scenarios using different bloc models, the graph below summarizes the impact of each bloc model on the length of the mine schedule.

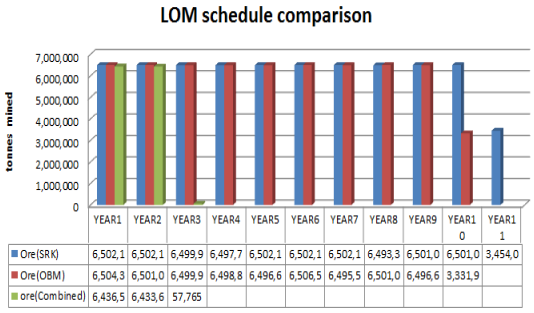


Fig 5. Compared KOV Mine schedules vs used models.

The official SRK (used in published technical reports), model provides a life of mine of 11 years at a rate of 6.5Million tonnes of ore mined per year. As mentioned precedently, we did use one ultimate pit shell and same pushback file for all models, and for the OBM model, the life of mine is shortened by one year ,it is running for 10years and the combined model is running for only 3years.Findings for the combined model tends to confirm worries of the Geology Department that was reporting ore that wasn't present in the initial SRK model,(which is good as a bonus ore)but the weakness here is that ,the ore found by geologists couldn't be incorporated in any optimization process because that ore wasn't included in the initial SRK model. We see that 22million tonnes of

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economic ore was reported in the economic model (table11), but ,due to the fact that most of that ore comes from grade control data, only 12 million tonnes of ore from table 14,was included in the life of mine, thus reducing the life very drastically.

Precedently, we said that the OBM model wasn't so different from the SRK model, although its provide a shorter life of mine, differences, are much more in the geological approach used in the construction of that model, which is not the purpose of this paper. This study can be conducted differently, by conducting an optimization process using a different approach and separate ultimate pits and pushback files, which may lead to even bigger differences in terms of life of mine and mine scheduling approaches. The aim here was to outline, how the geological information, once processed differently or insufficiently, can lead to huge mining discrepancies and involving a bigger mining risk in terms of investments.

V. CONCLUSIONS

The analysis that we have conducted here, was to compare the resulting life of mine when using three different bloc models (SRK, OBM, and the combined bloc model) different geological and geostatistical techniques were used to provide those models but wasn't the purpose of the paper, it is for our attention to understand how reliable must be a bloc model or ,most importantly ,a geological information before it can be used for strategic mine planning purposes, to avoid making disappointing decisions based on wrong or insufficient geological data. For the purpose of this study, the SRK model, as mentioned at the beginning, is reliable, but it is better, whenever possible to keep updating the model using additional exploration drill holes. This study is a beginning, and deeper analysis is to be conducted using different approaches of optimization and mine scheduling, but as a recommendation, it is better to keep using the SRK model until additional exploration drill holes information are available to update and make the SRK model better and to predict ore and waste more accurately than it is now.

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