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Mine extraction strategies - integration at tactical and strategic levels

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Although it is incumbent upon mine management teams to produce optimal extraction strategies at a local (tactical) level, it is crucial for these to be reviewed and assimilated into a broader (strategic) level perspective. The key considerations at each level of strategy are inherently different, even though the intention is to maximise the financial value in both cases. At the tactical level, the key considerations are operation-specific, and in the case of an underground mine can be split into micro design parameters that support a macro design. Typical micro and macro design parameters are:

Micro:
- Potential mining methods
- Development capacity in order to replace stope production per half level
- Buffer capacity within the half level ore transport system.

Macro:
- Mine infrastructure to access the orebody, and associated capital expenditure
- Mine scale: ore, material, and personnel transport configuration and limitations
- Utilities availability, including compressed air, water, and electricity
- Buffer capacity within the overall ore transport system
- Vertical hoisting capacity limitations
- Ventilation design
- Costs per reef type, as well as on-mine overhead costs.

Even though these factors are carefully considered and incorporated into on-mine value studies, it does not necessarily result in the highest value option for the region or company as a whole. At a strategic level, cognizance has to be taken of synergies and prevailing conditions on a broader scale, which would typically entail:

- Optimal sequencing and extraction of the orebodies across current mine boundaries
- Concentrator, smelter, and refinery infrastructure and capacities
- Best possible leveraging of various off-mine costs
- Highest return on capital expenditure, especially in an environment of limited capital (payback period and expected NPV and IRR)
- Company strategy, which would also take cognizance of market conditions (supply and demand dynamics)
- Introduction of new mining technologies.

It is evident that the focus points at tactical and strategic levels are very different, yet both processes are important in order to create maximum value from a mining business. However, it is crucial that these two processes are fully integrated and in effect complement each other. While the best way to exploit the orebody at a mine level has to be fully understood, it also has to be reviewed and assimilated into the 'bigger picture' for the company. This integration of the two processes is in fact a process on its own, and has to be deliberately and specifically managed.

This paper expands on the key considerations and managerial challenges applicable to both the tactical and strategic levels within a particular setting of conventional underground platinum mining, followed by the challenges and potential methodologies of integrating the two processes. Consideration is given to a hypothetical platinum mine case study that demonstrates the importance of integration of the tactical and strategic perspectives.

Introduction

Prior to 2005, the process of fully integrating tactical and strategic extraction strategies was not yet fully developed at Anglo American Platinum (AAP). Steps were taken to address the identified shortcomings from 2005, whereby 'strategic roadshows' were introduced, as well as periodical corporate reviews of the strategies and plans being formulated by the respective mines within the company.

However, it was during 2009 that the integration process took an important leap forward as a result of the establishment of a Mineral Resource Management (MRM) department within AAP, with both corporate and on-mine MRM structures. This greatly improved the company's capability to fully integrate tactical- and strategic-level extraction strategies. In particular, a comprehensive review process was established, whereby a series of multi-disciplinary reviews (MDRs) were held during the space of one year, which were designed to ensure thorough communication, understanding, and discussion of the various extraction strategy and business planning aspects. This led to significantly better alignment of tactical and strategic planning, with no perceived conflicts of interest, and improved value-add to the company as a result of better decision-making at a strategic level. This system was further enhanced during 2012 with the establishment of functional technical support at corporate level, which specializes in regional extraction strategy exercises, to better guide decision-making.

Figure 1 conceptually illustrates the AAP mine extraction strategy and planning cycle, which is guided by strategic-level criteria.

There were numerous learning outcomes and experiences gained during the process of better integrating tactical and strategic decisions, which this paper aims to discuss in more detail.

Figure 1. Interaction between tactical and strategic levels

Key tactical considerations

At the tactical level the key considerations are operation-specific in terms of the key aspects relevant to the specific mine or shaft that need to be investigated and understood. These key considerations for a conventional underground platinum mine are typically micro and macro design parameters:

Micro design parameters

- **Potential mining methods**. This parameter is largely influenced by the type and geological and geotechnical characteristics of the orebody, as well as the particular benefits and disadvantages of the various mining methods. Typical mining methods include scattered breast and down-dip methods, as well as variations of of trackless mechanized methods. When deciding upon a mining method at the tactical level, it is often critical to engage with strategic-level decision-makers, since there may be company-wide philosophies regarding standardization or mechanization of mining methods. In addition, there may be new approaches to current designs, such as optimal raise back length.

Figure 2 shows typical examples of types of mining methods being considered, namely down-dip and mechanized ultra-low profile. The emphasis in this particular instance was on pillar design due to a geotechnically complex UG2 Reef.

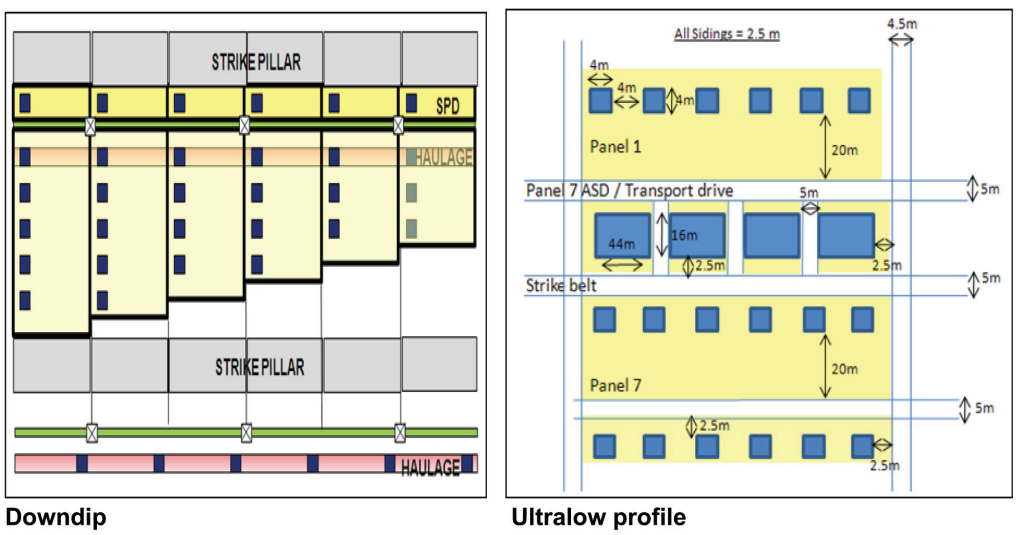

Figure 2. Downdip versus ultra-low profile mining methods

- **Development capacity in order to replace stope production per half level**. The amount of square metre production that can be sustained on a half level is closely linked to the haulage development advance. Therefore, this development capacity, which relates to the prevailing conditions and logistical situation, directly affects the level of production
- **Buffer capacity within the half level ore transport system**. This refers mainly to the raise line and boxhole design at the mine in question. Planned production levels are reliant on the buffer capacity, since the various activities on a half level are not constant and predictable. For example, locomotives that transport the broken ore do not always operate exactly as planned, which would necessitate some broken ore storage capacity, such as in boxholes.

Macro design parameters

- Mine infrastructure to access the orebody, and associated capital expenditure. Whether extending current mining operations on a particular reef or creating access to another reef horizon, the infrastructure and associated capital requirements need to be investigated. Typical additional infrastructure requirements are new decline systems, main crosscut development between reef horizons, sub-shafts and new vertical shafts from surface. Often more than one of these access methods is possible, which may require a trade-off study to resolve in terms of production profile versus costs versus required capital expenditure. A key determining factor is the spatial relationship between multiple reef horizons. Figure 3 is a schematic that illustrates an example of utilizing existing infrastructure to access a second reef horizon approximately 140 m below the current mining horizon, via a connecting inter-reef crosscut excavation. This often results in significant time and capital savings, as opposed to developing another decline system for the UG2 Reef
- **Mine-scale ore, material, and personnel transport configuration and limitations**. A key component of compiling tactical-level extraction strategies and business plans is the understanding of the configuration and constraints of getting people, utilities, and material into the workplaces and the broken ore out of the mine. In particular, long tramming distances of ore between shafts or sub-shafts can be very challenging, since there are limits to how much ore can be stored underground. It is obviously important to ensure that none of these constraints are breached when tabling a strategy or plan
- **Utilities availability, including compressed air, water, and electricity**. The planned production profile, as determined at the tactical level, needs to be supported by sufficient utility availability. A particularly relevant example of this is to ensure adequate electricity availability to support an extension to current mining operations in an environment of limited electricity supply
- **Buffer capacity within the overall ore transport system**. In addition to designing sufficient buffer capacity on each half level (or taking cognizance of the existing capacity), buffer capacity needs to be adequate to support fluctuations in the production profile. A common example of this is the blasting or construction of underground and surface silos. Due to the fact that the broken ore does not always move uniformly through the system, buffer capacity becomes crucial
- **Vertical hoisting capacity limitations**. Similar to the constraints relating to material and ore transport within the underground systems of a mine, production planning has to take cognizance of the amount of broken ore that can be hoisted via the vertical shaft. At the tactical level, potential opportunities to gain synergies with neighbouring mine infrastructure are not typically explored
- **Ventilation design**. Tactical-level decisions always need to be made within the context of a suitable and effective ventilation design for the mine. Even though a production plan can be executed within other constraints, it is imperative that an effective, cost-efficient, and low-risk ventilation design is in place. This would entail both macro and micro ventilation engineering, which encompass the overall ventilation design between levels, reef types, and surface, as well as how to ventilate individual workplaces such as stopes and development ends. In addition, ventilation design must take into account the various operating model factors, such as shift patterns and durations, as well as desired re-entry times. Figure 4 is a schematic example of macro ventilation design whereby the air flow between levels, reef types, and surface has been studied.

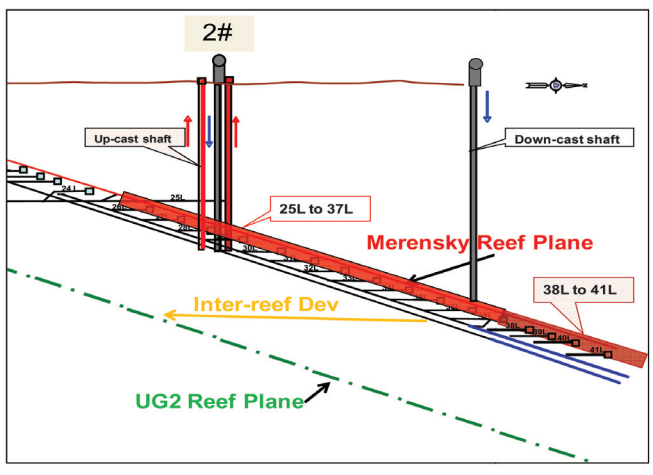

Figure 3. Utilizing existing infrastructure to access a different reef horizon

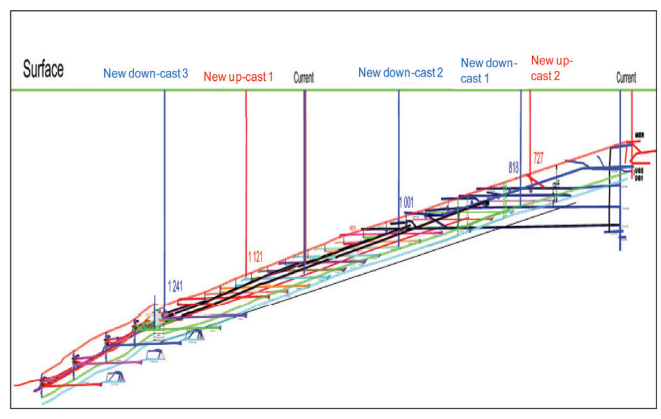

Figure 4. Example of macro ventilation design

- Costs per reef type, as well as on-mine overhead costs. Another key aspect at the tactical level is to understand the various cost structures. These include the direct mining costs of each reef or portion of the mine, which can vary significantly depending on depth and supporting infrastructure, as well as the chosen mining method. In addition, on-mine overhead costs, which are generally mostly fixed, need to be understood and leveraged or diluted through production volume in order to keep the total unit cost for the mine as low as possible.

When formulating tactics, a key managerial challenge revolves around the co-ordination of a wide variety of stakeholders from various departments, such as Mining Engineering, Mineral Resource Management, Human Resources, Finance, Engineering, Safety, and Projects. It is critical to obtain timely and quality input from each stakeholder, and this would need to be co-ordinated by the appointed custodian of the process.

Key strategic considerations

Even though the key tactical factors are studied and incorporated into on-mine strategies and plans, this does not necessarily result in the highest value option for the region or company as a whole. At a strategic level, cognizance has to be taken of synergies and prevailing conditions on a broader scale, which would typically entail the following.

- **Optimal sequencing and extraction of the orebodies across current mine boundaries**. Although tactical-level strategies do typically account for boundary optimizations between neighbouring mines, they do not generally take cognizance of regional strategies or synergy opportunities. The on-mine team would therefore assume that the ground within their current mine boundaries should be mined from the existing infrastructure. However, trade-off studies performed across mine boundaries may deliver a different result, which needs to be communicated back to the on-mine team as part of the tactical/strategic integration process. Such trade-off studies would take cognizance of:
  - **Orebody characteristics**. It may be more beneficial to approach the orebody from alternative directions, depending on reef width, low-grade zones or large-scale geological features that should be avoided
  - **Large-scale mine design and infrastructure requirements**. The appropriate studies need to determine what infrastructure does not need to be installed when mining across current mine boundaries. For example, sinking one large-capacity shaft instead of two smaller shafts
  - **Timing and scale of metal production**. Depending on the sequence of ore body extraction, there will be significant differences in the timing of the first production ounces, the subsequent ramp-up profile, as well as steady-state volume. This has a major effect on the revenue stream, especially in view of the importance of the time value of money in financial valuations.

Figure 5 is an example illustrating how the IRR of a project can vary according to rate of production ramp-up at certain levels of capital expenditure

- **Concentrator, smelter, and refinery infrastructure and capacities**. On-mine infrastructure constraints need to be taken into account at the tactical level. Similarly, centralized infrastructure constraints must be accounted for and optimized at the strategic level. This entails a comprehensive understanding of the metallurgical process and its unique characteristics and constraints, which may include the surface transport of the broken ore to these facilities
- **Best possible leveraging of various off-mine costs**. A view needs to be taken at the strategic level of how the various off-mine costs are structured, and how they are best leveraged for maximum value. This does not necessarily mean to simply maximize volume from every mine; it cannot be a case of production at any cost. Rather, it needs to be maximum value production, which may include curbing production from certain areas, dependent on operating cost or required capital funding to commence and sustain production
- **Highest return on capital expenditure, especially in an environment of limited capital availability**. Given the current economic climate, getting a suitable return for capital funds invested is now more crucial than ever, especially when such funding is limited. This implies that, at the strategic level, decisions have to be made regarding the allocation of capital funds. In essence, the tactical-level mining operations are competing for limit funding, and as such will construct their best possible business proposition. Therefore, in order to arrive at a tactical-level plan that can be funded, it is crucial that decisions regarding capital funding at the strategic level are properly communicated.

An important initial indicator of where a suitable return on investment may be found is revenue per square metre of production, per reef, per mine. Figure 6 displays an example of such an analysis at a certain point in time

- **Company strategy that would also take cognizance of market conditions (supply and demand dynamics)**. With an appropriate market analysis in place (especially for volatile markets), it is incumbent upon the strategic-level team to determine the required ounce profile for the company, for delivery into the market. This required ounce profile naturally has to be sourced from the mines within the portfolio of the company, or from joint venture partners. Therefore, key decisions have to be made regarding the production profile from each mine, which may result in a particular mine being required to produce more (if possible) or fewer ounces. This top-down-goal type of information needs to be communicated early in the planning process

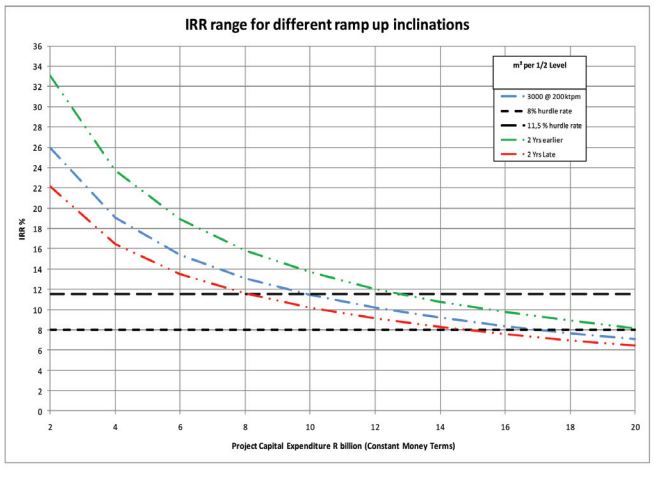

Figure 5. Varying IRR according to production ramp-up

in order to avoid rework by the on-mine team. Similarly, at a tactical level, a certain level of production flexibility would need to be accommodated that can be relatively easily 'switched' on and off if or when required

- **Introduction of new mining technologies**. As part of the ongoing drive to improve safety and efficiency in their mining operations, it is often a strategic imperative for companies to embrace new mining technology. Such strategies are usually formulated at the strategic level, and thereafter introduced at the tactical level for implementation.

The key strategic-level managerial challenge is thorough and timely communication. It is imperative that strategic-level decisions are clearly communicated to the on-mine teams, at a time that the information can be applied while still delivering the required quality of tactical-level strategy and plan. For example, it would be too late to issue a new mining technology directive when the on-mine business plan is already half complete.

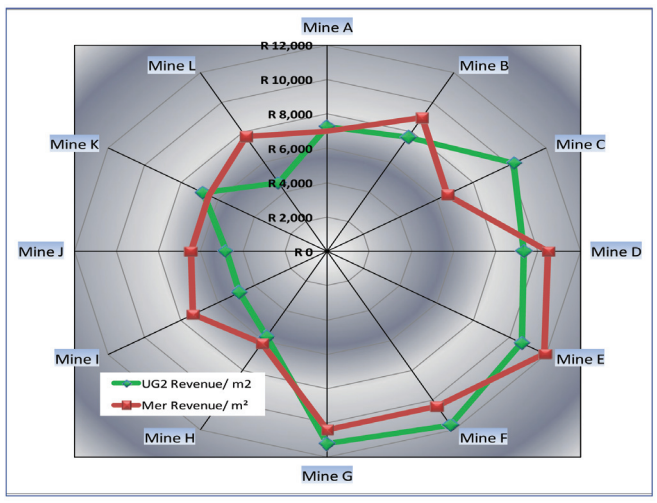

Figure 6. Revenue per square metre of production analysis

Integration of tactical and strategic levels of plan

The key to comprehensively integrating tactical and strategic levels of plan is to ensure proper collaboration between all parties involved. This demands a deliberate and structured communication process, which can take various forms, but a suggested approach is to employ systematic multi-discipline reviews (MDRs). The MDRs entail the on-mine team presenting aspects of their tactical mine extraction strategy and resultant business plan to a multi-discipline specialist and corporate team for discussion and ratification. Several MDRs would be scheduled during the course of a year, starting with mine extraction strategies, through to detailed production planning based on company top-down goals, labour and costs, and culminating in the mineral resource/reserve statements for public reporting. Importantly, prior to and during the mine extraction strategy phase, a centralized mining engineering team can already be performing option analysis studies. This will provide valuable guidance to the on-mine tactical level team.

Figure 7 models the interaction between tactical and strategic aspects at AAP, whereby a business plan is compiled at the tactical level but is guided by strategic-level aspects.

It is essential that, as part of the process, each MDR is preceded by a specialist single-discipline review (SDR) per relevant discipline, in order to ensure the quality of inputs. This early review of the technical detail is critical to ensure the validity of the subsequent MDR discussions and decisions. For example, a fully qualified, knowledgeable, and experienced ventilation engineer needs to validate the ventilation design supporting a production plan that is going to be presented at the ensuing MDR.

Even though the MDR/SDR process is thorough and

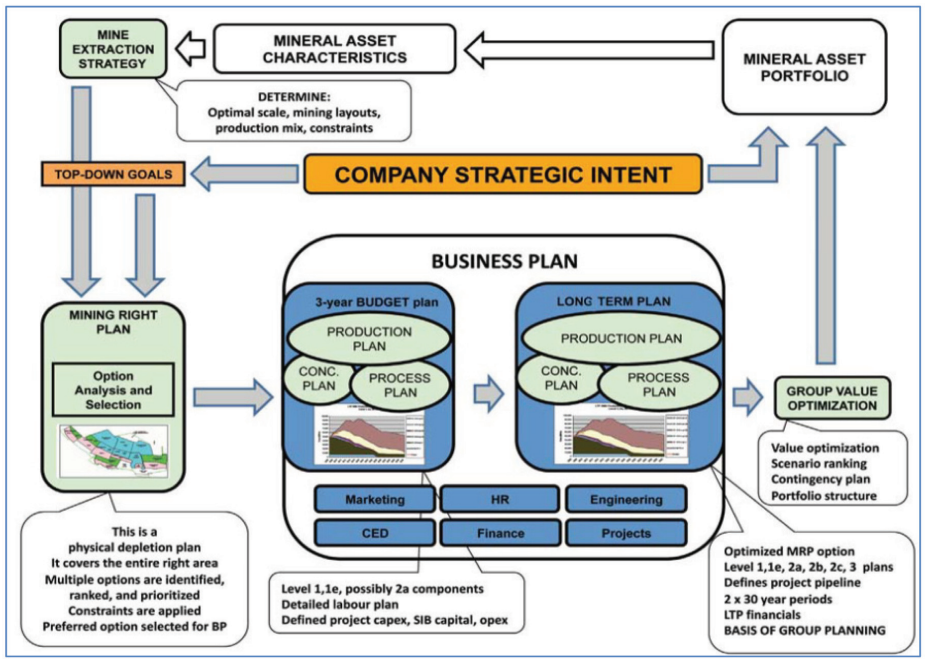

Figure 7. Interaction between tactical and strategic levels

systematic, a challenge that could still arise is a requirement to make changes to the tactical-level strategy or business plan presented by the on-mine team. Such a change may typically arise from new insights into the strategic level strategy for the company, for example, a tightened constraint on capital availability. This may put severe pressure on the on-mine team to rework the tactical strategy in a relatively short period of time while maintaining the required levels of quality output, thereby potentially introducing risk to the tactical-level strategy or plan. However, such risk may be mitigated by allowing sufficient time in the strategy/business plan cycle to address rework, as well as to obtain additional assistance from the specialists involved in the SDRs.

As a final step, once a tactical-level plan that is aligned to the strategic-level plan is finalized per mine, it is imperative that executive approval is sought. This, in effect, is the final review in the process, and makes the tactical- and strategic-level plans official.

Case study

An approach to tactical-level extraction strategy analysis, as well as the importance of integrating strategic- and tactical-level extraction strategies, can be vividly demonstrated in a platinum mine case study.

Setting the scene

Between September 2011 and January 2012, 'Central Mine' underwent an exhaustive tactical-level extraction strategy options study. This work was absolutely imperative in order to arrive at the financially most optimal option to exploit the Merensky and UG2 orebodies.

As shown in Figures 8, 9, and 10, the Merensky Reef had already been extensively mined via vertical and decline shafts, with two remaining investment centres (ICs) between 25 and 37 levels and 38 and 41 levels. The UG2 Reef, which is 140 m below the Merensky, had been less extensively mined, with several ICs remaining between 19 and 41 levels. As part of each IC name, the level of current project pipeline study work is reflected:

- Ongoing mining operation: L1
- Project in execution: L1e
- Feasibility study: L2a
- Pre-feasibility study: L2b
- Conceptual study: L2c
- Desktop study: L3

It is important to note that, due to the different mining histories of each reef, they did not have corresponding boundaries. Both orebodies dip at 9 to 11 degrees approximately towards the north.

Given this setting, several options were investigated on the best way to maximize value from the orebodies, based accessing the UG2 orebody by leveraging off existing Merensky infrastructure as opposed to developing a new decline system for the UG2 Reef. This approach had the dual benefit of quicker access to the UG2 as well as lower capital requirements. Crucially, No. 2 shaft does not extend down to the UG2 Reef, and does not have rock hoisting facilities; all ore had to be hoisted from No. 1 shaft. Therefore, in all of the options, cognizance had to be taken of which ICs report directly to the vertical shaft, and which ones first had to transport ore via decline belts.

Options analysis

Subsequent to preliminary option analysis, the following three options were chosen for further study. Note that in each option the four ICs below the belt capacity line need to be hoisted via the said belt.

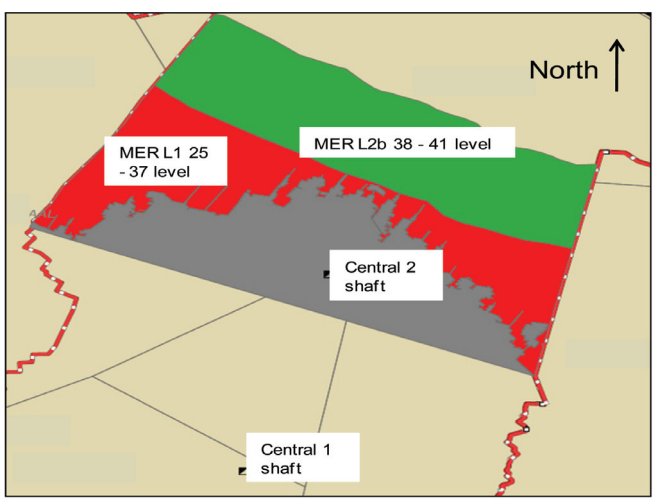

Figure 8. Central Mine Merensky investment centres – plan view

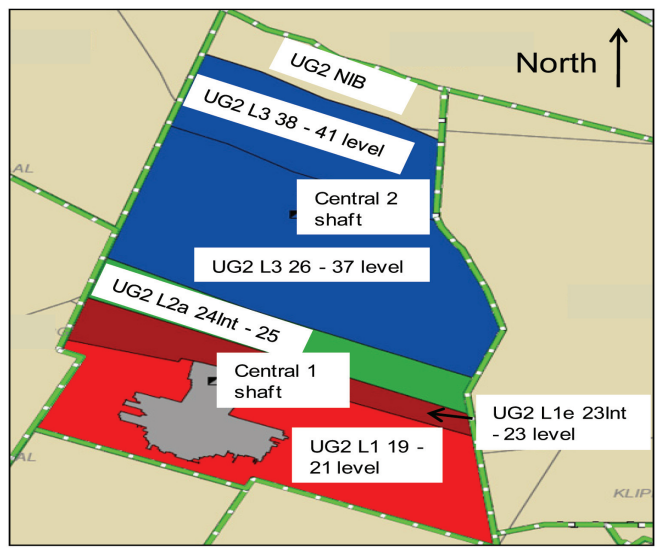

Figure 9. Central Mine UG2 investment centres – plan view

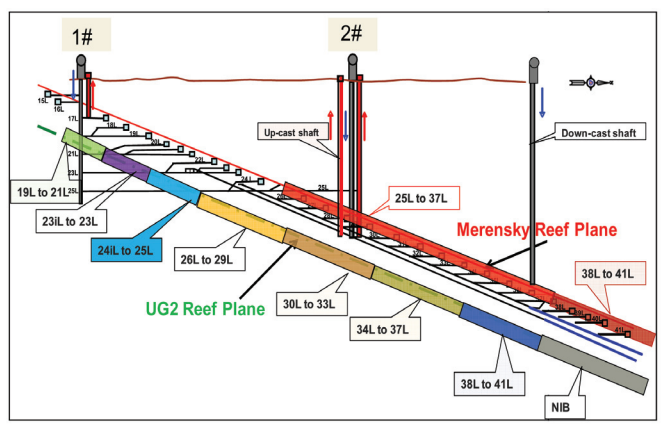

Figure 10. Central Mine – section view

Option 1: Maximize the higher grade Merensky Reef, and fill the belt capacity with UG2 once the vertical hoisting capacity allows when shallower UG2 production starts to decline (Figure 11).

Option 2: Maximize Merensky Reef, and fill the belt capacity earlier with deeper UG2. The required vertical hoisting capacity is made available by reducing and stretching the UG2 L1 production profile, but the fixed costs associated with the decline system are better leveraged by a higher decline production profile (Figure 12).

Option 3: Delay deep high-cost and high-capital (decline system extension) L2c Merensky Reef and fill the belt capacity earlier with UG2 from levels 26 to 37. The required vertical hoisting capacity is made available by reducing and stretching the UG2 L1 production profile, but the fixed costs associated with the decline system are better leveraged by a higher decline production profile (Figure 13).

Upon testing each option with suitable financial modelling, option 1 yielded the highest value, in spite of a high capital component to extend the Merensky decline system. This value was largely assisted by the higher production profile of the shallower UG2 L1. However, the deep UG2 38 to 41 level IC could not carry the associated costs and capital required for extraction, in effect becoming an uneconomic production 'tail'.

Strategic and tactical integration

As per the multi-discipline review process, which was established specifically to ensure strategic/tactical integration, the above three options and their respective results were presented. Therefore, the key strategic-level considerations discussed previously were scrutinized, with the following important observations:

- The UG2 38 to 41 level IC did not have a positive cash flow, mainly as a result of additional infrastructure and overhead costs that it could not share with other ICs, since it was the last IC in the overall profile
- The MER 38 to 41 level IC had a large capital requirement of approximately R1.3 billion (2012 money terms) in a climate of limited capital availability
- The tactical-level strategy had not taken a view on the possibility of optimizing the regional extraction strategy across mine boundaries.

In order to alleviate the abovementioned key observations, the decision was taken to investigate the impact of Central Mine ceding the two 38 to 41 level ICs to neighbouring mines. This had the desired effects:

- The UG2 38 to 41 level IC was mined from neighbouring operations, where it could be extracted in combination with other ICs, thereby reducing the overhead cost load
- Similarly, the MER 38 to 41 level IC was planned for extraction from neighbouring mines, thereby negating the need for significant project capital. Decisively, the neighbouring mines were in any case planning to access their deeper Merensky Reef through project capital, and could now also access the deeper Merensky of Central Mine.

Figure 14 illustrates the resultant production profile for Central Mine, which is now significantly modified due to the tactical/strategic integration process, and which resulted in a substantially higher value proposition for the company.

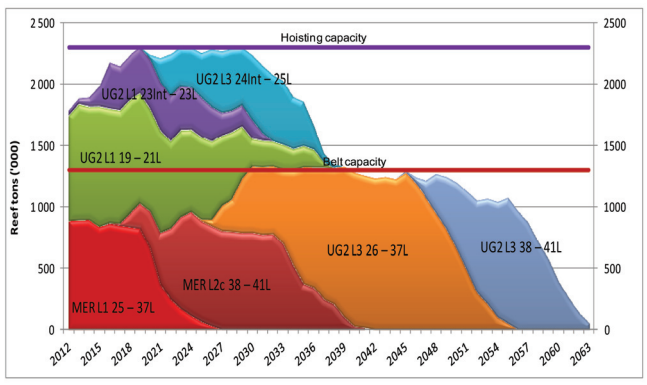

Figure 11. Tonnage production profile for option 1

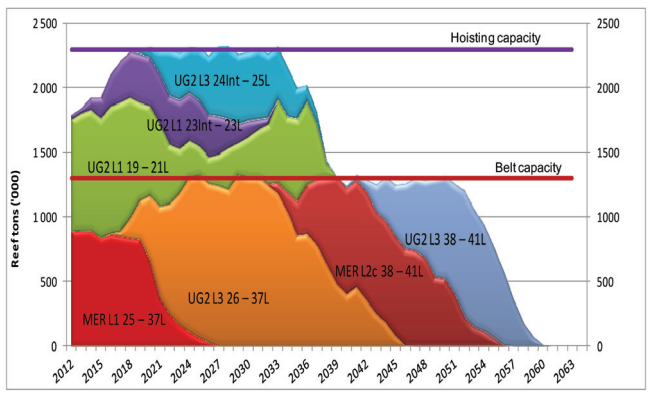

Figure 13. Tonnage production profile for option 3

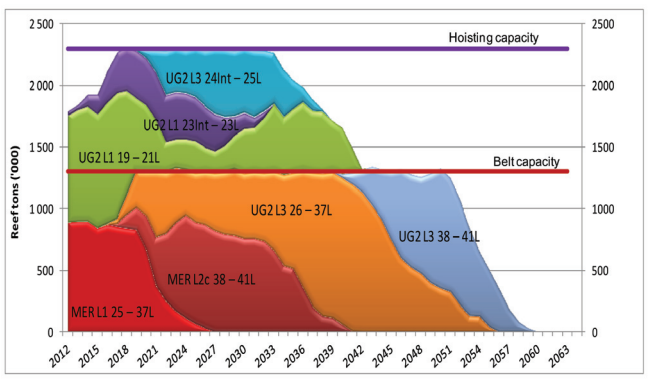

Figure 12. Tonnage production profile for option 2

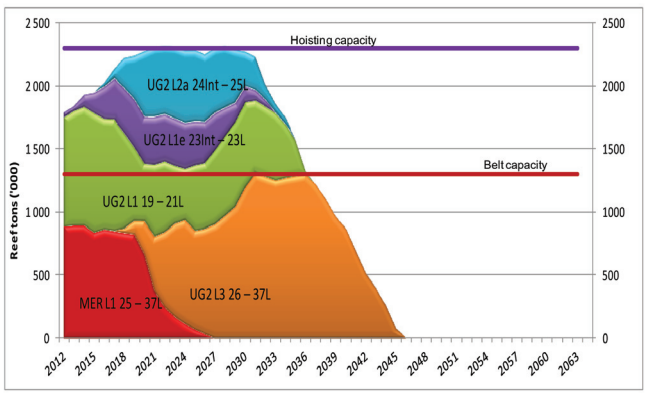

Figure 14. Tonnage production profile for tactical/strategic integration

Conclusion

In order to maximize value for a mining business, sound mine extraction strategies have to exist at both the strategic and tactical levels. However, the key factors to be taken into account at each level are inherently different. It is therefore crucial that these strategies are properly integrated, and that suitable business processes exist to ensure that effective integration occurs. Such processes need to be systematic and would include centralized option analysis and structured multi-discipline reviews, preceded by quality-assuring single-discipline reviews that ensure the relevant issues are addressed. In addition, the multi-discipline reviews facilitate appropriate collaboration in order to ensure proper integration of the two levels of strategy.

As per the case study, a mining business can significantly benefit from understanding the strategic-level context and strategy, and interacting at the tactical level to add significant shareholder value. Without the integration structure and process, genuine opportunities and synergies may be lost, with large portions of the orebody potentially being economically sterilized or undervalued.

Acknowledgements

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