LANE, G.R. and WYLIE, B. Case study: a value driver tree as a means of integrating value drivers across disciplines and activities. *The 6th International Platinum Conference, 'Platinum–Metal for the Future',* The Southern African Institute of Mining and Metallurgy, 2014.

Case study: a value driver tree as a means of integrating value drivers across disciplines and activities

G.R. LANE and B. WYLIE
Cyest Corporation

Mining companies are traditionally managed in silos, with each discipline owner or department head focusing on and managing key performance indicators (KPIs) very specific to their area of control. For example, the individual responsible for the 'drilling and blasting activity' focuses on KPIs relating to improving that activity, often without understanding the impact on downstream activities such as loading, hauling, and processing.

The support functions of human resources (HR), finance, and engineering are very functionality-focused, and often just see their role as administrative and having no direct control on production and therefore company performance.

This paper presents a case study of how a value driver tree (VDT) model of the full mining company value chain was used in a structured workshop with mining, engineering, finance, and HR to show that every activity and functional area has value drivers that they control. These in turn impact other activities that have a direct impact on production and therefore overall company performance.

Some important insights were gained, where functional areas that saw themselves as purely administrative realized that they could make value-based decisions that directly impact company performance. For example, 'engineering' focused exclusively on availability for all equipment, without an appreciation of reliability, utilization, and consequential downtime.

A VDT model is a visual representation of a business model that relates all the business variables and value drivers for the complete business across the entire value chain.

Introduction

This paper describes, using a case study, the use of a VDT model as a means of integrating all the activities and functions and associated metrics across a mining value chain.

The mining environment is especially prone to the dangers of fragmented planning because of its inherent technical complexity, combined with a high degree of operational and market uncertainty (Lane *et al*., 2009). Therefore mining companies are traditionally managed in 'silos' with individual responsibility and accountability for individual activities, functions, or disciplines across the mining value chain. Performance metrics (KPIs) are therefore focused on that individual's area of control, and most often do not pay respect to the impact on other disciplines or activities across the entire mining value chain.

A mining operation is a set of activities that are interconnected in a mining value chain (drill, blast, load, haul, crush, process, and sell, for example), with supporting activities such as engineering, human resources (HR), finance, and mineral resource management (MRM). The overall performance of the mine, in terms of throughput from this 'system' of interconnected activities and ultimately value created, is dependent on the performance and decisions made in each separate activity and supporting function.

Figure 1 highlights this challenge, where KPIs for each area of responsibility impact each other and ultimately the operating performance of the mine.

For example, decisions made by engineering around maintenance procedures, scheduling, and priorities will have a major impact on the mining operation's production capacity for a given period. Just synchronizing maintenance scheduling and prioritizing maintenance on critical equipment in the bottleneck activity minimizes the production downtime of that activity, which has a major impact on the overall system throughput. The engineering KPI on most mining operations is 'availability' of equipment, but this does not pay respect to reliability and therefore the consequential downtime on up- and downstream activities, and therefore the resulting impact on the value stream throughput.

This paper describes the use of VDT models to expose the underlying value drivers and logic of the business across all the activities of entire value chain.

A VDT is a way of visualizing a model of a business in a way that links the value metric (what management or stakeholders care about) to the operational drivers (the things that can be influenced to change the value metrics) (Cambitsis, 2012).

In the case study that follows, a VDT model of an opencast diamond mining operation was used in a series of workshops with each of the leadership teams from the individual disciplines and support functions across the mine. Teams from HR, finance, engineering, and mining had to identify value drivers under their respective control

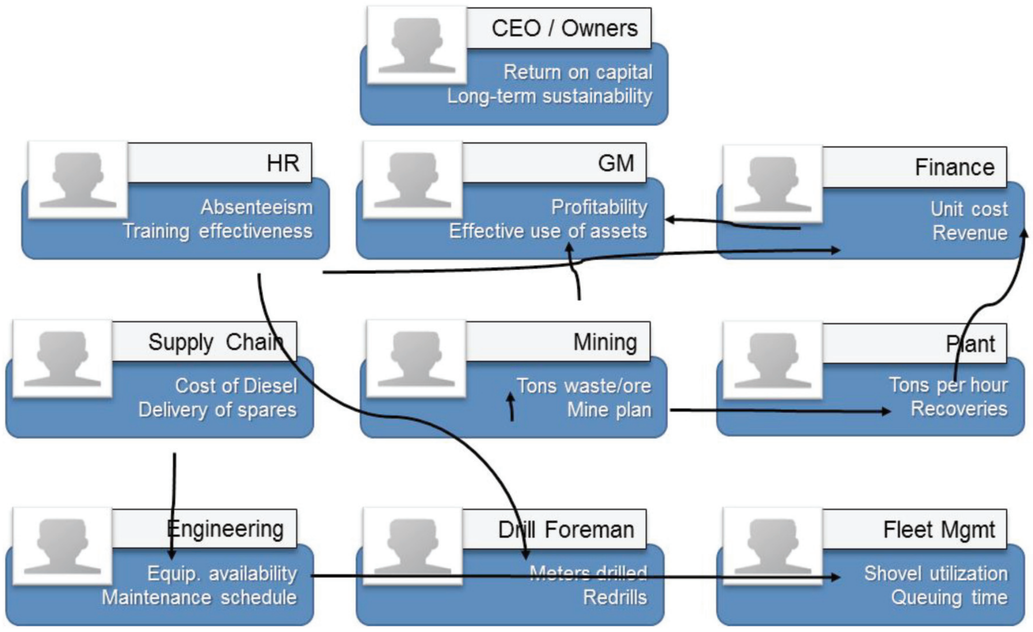

Figure 1. KPIs for individual areas of responsibility impact other activities and therefore overall performance

that would have a significant impact on the operating profit of the operation.

Some important insights were gained, where functional areas that saw themselves as purely administrative realized they could make value-based decisions that directly impact company performance.

What is a value driver tree model?

Cambitsis (2012) describes a VDT as a way of visualizing a model of a business in a way that links the value metric (what management or stakeholders care about) to the operational drivers (the things that can be influenced to change the value metrics). In this respect, a VDT is the visual representation of a mathematical model of a business (or portion thereof). Most people are familiar with spreadsheet-based models of a business, often used for planning or budgeting purposes. In essence, all these models are nothing more than a series of relationships relating input variables to output variables. The complexity often comes in the number of the variables and relationships, how they are organized, and how transparently these are represented.

Figure 2 shows an example of a simple VDT summarizing the costs and production value drivers linked to profit. This VDT visualization is functionality of the Cyest Modelling Platform Technology.

The Cyest Modelling Platform Technology (previously called Carbon) is an object-oriented multidimensional enterprise modelling environment developed by Cyest Technology to meet the needs of business modelling (Lane, 2009).

Case study – using a VDT model across the mining value chain

This case study describes how a VDT model of an opencast diamond mining operation was used in a series of workshops with all the disciplines and functions across the mine to identify value drivers within their individual control that impact other activities in the value chain, and ultimately overall operational performance (operating profit).

The VDT model was configured in the Cyest Modelling Platform Technology, and the final model described in this case study has been implemented at the operation as a performance management and asset optimization capability.

The VTD of the business

A VDT-based modelling solution was configured and implemented for an opencast diamond mining operation that related the underlying metrics and value drivers for each of the individual activities in the value chain (drilling, blasting, loading, hauling, and processing).

Figure 3 shows schematically how a VDT model of a complete business is constructed to combine a summary VDT of the business and VDT models for each of the underlying activities.

The equation below defines a generic building block for each activity in the VDT for calculating that activities capacity (quantity produced for that particular period of time). This could be for a piece of equipment, such as a truck, or milling line, or an activity as a whole such as drilling and crushing. In either case the input is the

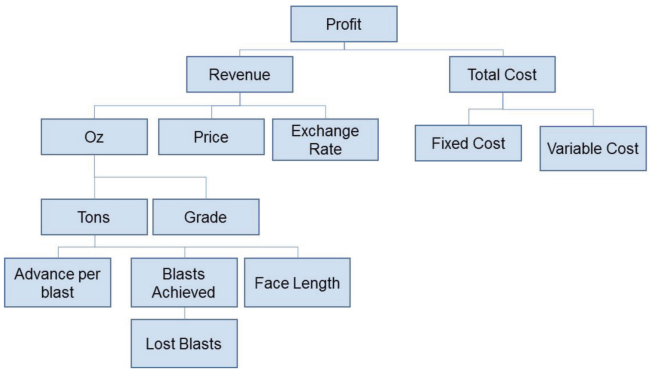

Figure 2. An example of a value driver tree for a generic mine

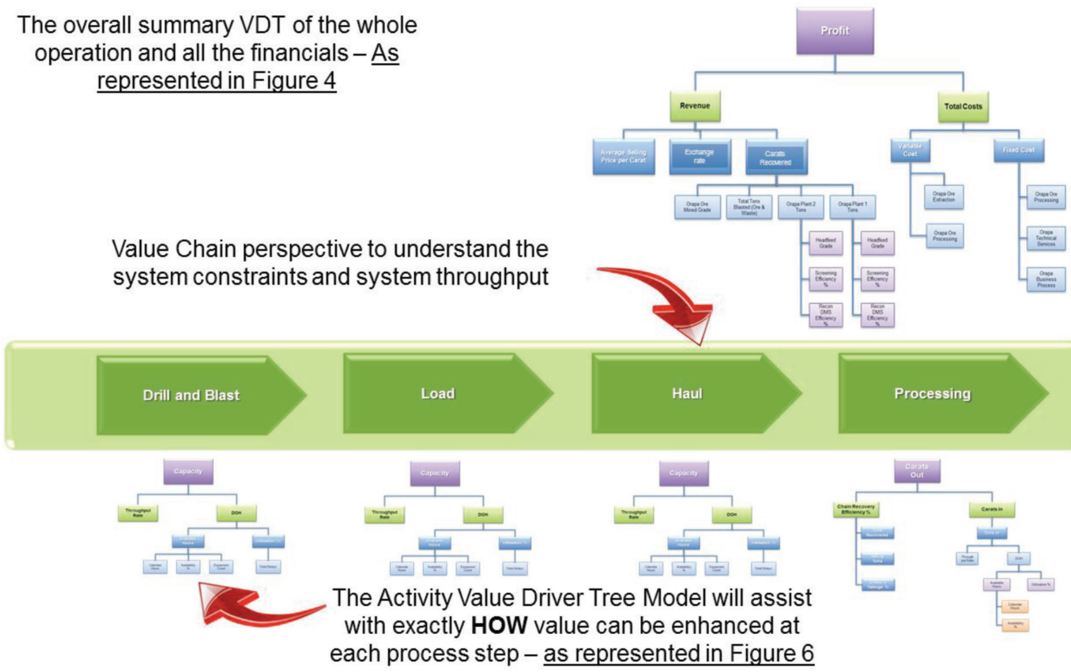

Figure 3. Schematic showing the architecture of a complete VDT for a typical opencast mining operation

quantity of product (be it metres drilled or tons crushed), and this is a direct function of the amount of time the activity or equipment is operating and the rate at which it operates. This is a reasonably universal way of describing any production activity, and in fact can even be applied to service activities (Cambitsis, 2012).

Quantity produced = Production rate x Net production time

Depending on a client's specific time model and the data available, this can then be expanded to the actual underlying value drivers impacting the production rate and net production time. Figure 4 shows a generic VDT where the net production time and available time has been decomposed.

The final VDT built for each activity for this particular client in this case study used this basic building block, which was expanded based on the actual underlying data available from the drill and blast system, fleet management system for load and haul, and the plant SCADA.

Interestingly, we have found from our experience with implementing VDT models at opencast operations around the world that the load and haul fleet management systems generally have good data, but that this information is underutilized for understanding performance variance or for optimizing the load and haul activities.

Figure 5 shows an example of the final VDT model for the hauling activity only. This VDT will be used in this paper as the case study of how the VDT model was used in the individual workshop sessions with the disciplines and functional areas.

The summary-level financial VDT model, taking into account the activities and the resulting system throughput and costs, is shown in Figure 6.

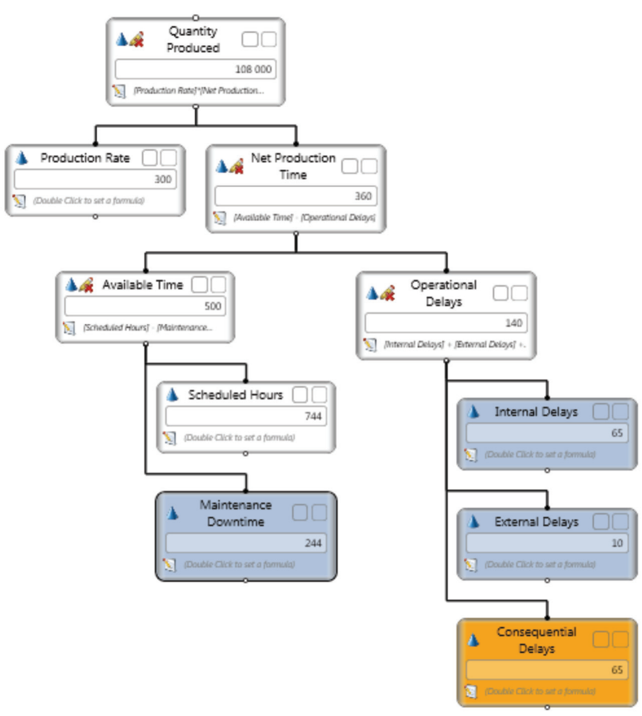

Figure 4. Decomposing available time

The overall client solution

At this particular client, the VDT model was part of an overall asset optimization and performance diagnostics solution that was recently implemented.

The final functionality that the solution offered was as follows:

1. **VDT model** of each activity to visually represent the value drivers and assist people to understand the relationship between the variables.
2. **Key value drivers analysis** to identify the most important value drivers under management control that have the largest impact on operating profit.
3. **Reason for variance analysis** to identify the root-cause metrics that have the largest impact on performance between actual, budget, best demonstrated, and benchmark. This is one of the

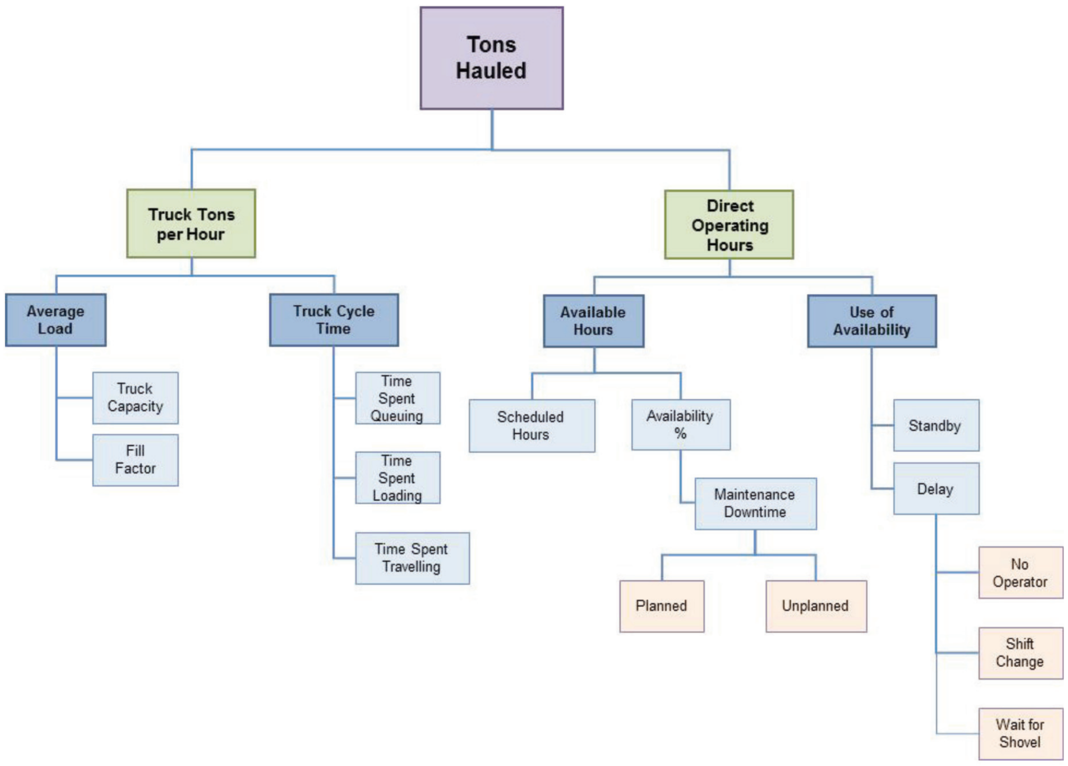

Figure 5. Final VDT for hauling activity

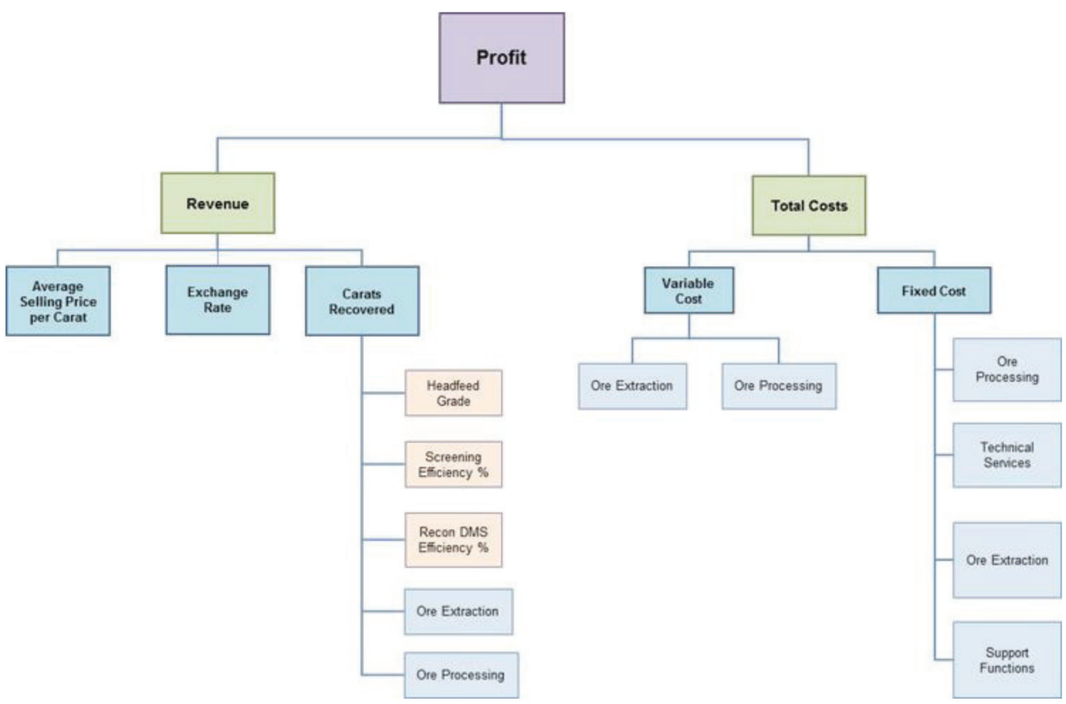

Figure 6. Overall Financial VDT taking into account system throughput

most valuable pieces of analysis, which focuses management attention on the priority areas causing performance variance.

4. **Capacity analysis** of the activity value chain taking into account the degree of coupling between activities and therefore system throughput. This shows the static and dynamic activity constraints, taking into account the consequential downtime between activities due to starving and choking – in other words, the concepts around the Theory of Constraints
5. **What-if scenario analysis** to allow management to test different initiatives and scenarios to improve the system throughput and operating profit after identifying key value drivers, reasons for performance variance, and activity bottlenecks.

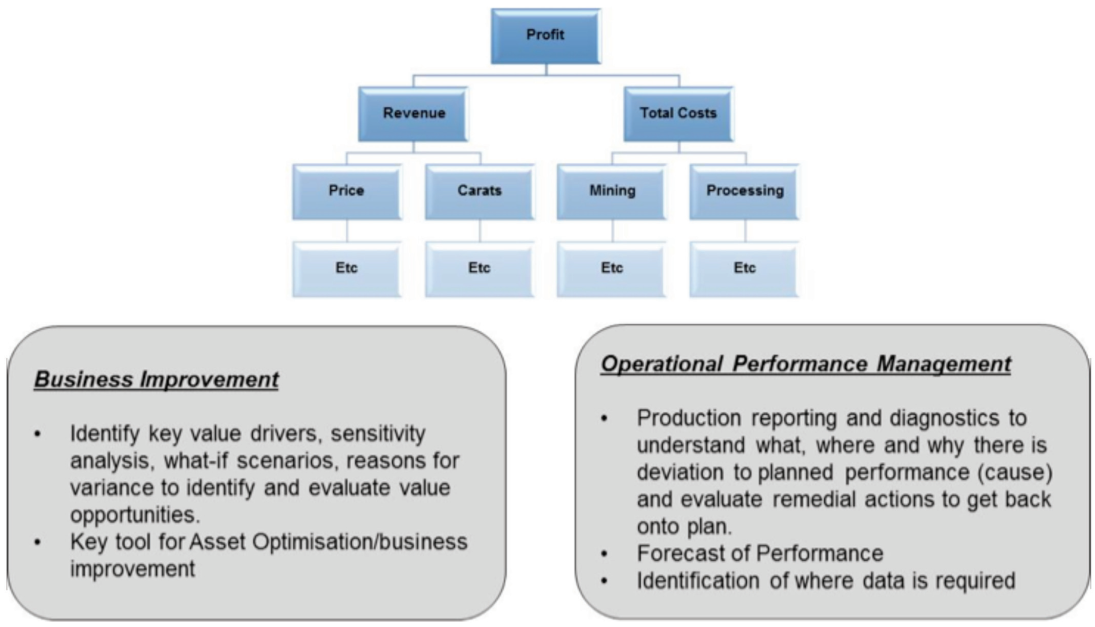

Figure 7. Positioning of the VDT solution

At this opencast mine the asset optimization function was managed and reported as a separate activity with the aim of identifying initiatives to improve operational performance.

The reason for the solution being implemented as both an asset optimization and ongoing performance diagnostics solution was to entrench the 'mindset' of asset optimization and continuous improvement into the daily and monthly operational performance management processes and review meetings.

Figure 7 shows the different uses of the model from an asset optimization and performance management perspective.

Using the asset optimization functionality around understanding key value drivers that have the largest impact on performance, the 'reasons for performance variance' between actual and budget and the dynamic system constraints gives management a powerful diagnostics capability on an ongoing basis to prioritize management actions as part of normal performance management. In other words, the tool encourages management to stop fighting all the fires and focus on the most critical items causing performance variance.

How the VDT model was used in a workshop

The final VDT model was used in a series of interactive facilitated workshop sessions with the HR, finance, engineering, and mining departments on the mine.

The intention of the facilitated workshops was for each discipline to interact with the VDT model and identify key value drivers that they could influence which could impact operational performance, and at the same time understand the impact that these value drivers had on other activities in the value chain and the concepts around capacity analysis or Theory of Constraints.

These workshops were held individually with the manager and respective teams for HR, finance, mining, and engineering. Individual workshops were held with each discipline for two reasons – firstly, to allow the team the time to focus on what they believed to be 'their' value drivers, and secondly, to give them a secure environment to ask questions to clarify aspects of value drivers and modelling. The latter point came from our previous experience, where it was found that in combined workshops, discussions were dominated by engineering and mining representatives and HR and finance did not participate actively.

The format of the workshop was to facilitate an interactive session with each discipline where the actual VDT model was used in discussions. The teams were asked to discuss which value drivers their respective disciplines could impact, what they believed was the impact on operating profit, and how they could influence this.

The value drivers identified by each discipline from each of the workshops were collated into an overall presentation that was given at a combined EXCO meeting of all the discipline heads and the GM of the mine.

For this case study, the hauling VDT model in Figure 5 will be used to demonstrate the findings and results from each of the workshop sessions with the disciplines.

Session with HR management department

The session with the HR team was found to be one of the most valuable sessions. Generally in all combined group meetings with all disciplines, HR do not participate. At the start of this workshop session the HR team initially did not engage and responded that 'they were an administration function and had no real impact on operating profit other than on labour cost'.

This very quickly changed during the facilitated discussions around some key value drivers which HR could actually impact and which have a significant impact on operating performance. The HR team then started to engage and the examples started to flow freely.

Below is a summary of some examples based on just the hauling activity in Figure 5.

a) From the VDT model and using historical data from the last 24 months, it was demonstrated to the HR team that one of the largest reasons for internal delays on hauling was due to 'operator not available'. Here is a multi-million dollar piece of equipment with costs incurred on maintenance so that it has 'available hours' and it stands due to lack of an operator. On this particular mine the hauling was the constraining activity, so this 'hauling' lost production had a direct impact on value chain throughput and therefore the operating profit of the mine.

Over the past 24 months the internal delay just for 'no operator' equated to 19 000 hours, which is 113 operator months or an additional five operators per month over this 24 month period. Using the VDT model it was demonstrated to the HR team that the impact on operating profit of having an additional five operators per month, taking the costs into account, equated to over US$100 million additional operating profit over the 24-month period. This is a real opportunity loss of profit, as hauling was at that stage the constraining activity.

The HR manager mentioned that there was actually pressure to reduce the labour complement further. The HR department had asked in the recent budget for an additional five haul truck operators, but this had not been approved as the budget had to be cut by 10%.

The HR team indicated that if they had the VDT model they could have motivated the additional operators on a value creation basis.

b) This example initiated many other examples from the HR team.

   For example, the HR manager mentioned that the finance department had recently cut the training budgets due to cost-cutting measures requested from the corporate office. The mine still has to train the operators, so they have found a 'cheaper' service provider for training, which required the operators to leave the mine for a longer period for training than with the traditional approach. The session was able to demonstrate, using the VDT, that the additional 2 days that the operators were off site for training actually destroyed hundreds of times more value in terms of lost production compared to the training cost, of the more expensive provider.

   HR also mentioned the quality of training of operators and the impact it may have on cycle times and fill factors due to operators not understanding the impact they have on overall performance.

c) Facilitated discussions were also held around how HR planned the number of operators required. It was found that the manpower plan is not actually based on the production plan and underlying drivers. Ideally, the production schedule should determine the number of pieces of equipment required based on their respective capacities. The capacity is based on the underlying driver assumptions as shown in Figure 5. The number of pieces of equipment and the operating hours should be the driver of the number of operators.

   In addition, it was found that HR planned to increase the number of operators in service by only 14%. The workshop listed all the reasons why an operator might not be available; annual leave, ad-hoc leave, compassionate leave, AWOL, annual training, union meetings, management meetings, safety meetings, safety induction, administration etc. and found that an increase of 25-30% would be more realistic.

The HR team felt empowered as they now understood how they could directly impact the value drivers of the business. The focus of the discussion had changed from labour cost to labour value.

Importantly, they understood the concepts of value chain modelling and Theory of Constraints, and that in the activities that have additional capacity, the concepts described above would not enhance value. Therefore the activities and value drivers cannot be looked at in isolation, but must be considered in the context of the whole value chain.

Session with finance department

The workshop with the finance manager and finance team yielded the same level of understanding and engagement as from HR.

The facilitator gave the example of the operators and training that had been discussed with the HR department and Finance agreed, that in most instances, every year at budget approval time the emphasis was on cost cutting. In fact, the function of the cost accountants on the mine was to manage the cost line items only.

A VDT model would integrate all the technical, production, and resulting costs and economics allowing for an integrated value-based view of the business.

Some of the findings from the workshop were as follows:

a) The finance team agreed that management generally focus only on cost without an understanding of the impact on production and therefore operating profit. Often decisions are made to cut budget costs that have an impact or add risk to the operation's ability to meet its production throughput targets.
b) They all agreed that budgeting must be done in the context of an integrated VDT model of the complete business value chain so that 'value-based' decisions can be made.
c) Figure 8 was used as an example to show the cost accountants that an increase in diesel cost of the hauling fleet may not necessarily be a bad thing, if they understood the drivers of diesel cost and the 'reason for variance' in the cost increase.

Using Figure 8, the cost accountants could understand that the cost of diesel is driven off the following drivers using the 'reason for variance' functionality of the solution.

Diesel cost is driven off the following two drivers: **diesel price** or **litres of diesel** used.

- If more **litres of diesel** were consumed; was it due to an increased **diesel consumption rate per hour**, which may be a truck maintenance issue, or to increased **operating hours** of the truck?
- If the increase is due to **an increase in operating hours**; is this due to increased **production** (which is actually a good thing) or due to the truck's **throughput rate per hour** being lower?
- The lower **throughput rate per hour** may be due to a lower **fill factor** or increased **cycle times** related to loading, queuing, or travel times.

The cost accountant could immediately understand the link due to the visual representation of the logic in a VDT.

Depending on the granularity of the data available in the fleet management system, the VDT could include even more detailed value drivers to capture all aspects of cycle time, travel distance, or even diesel consumption rate related to speed, load, and gradient.

Session with mining department

The workshop session with the mining department was very interactive with opinions from everyone, as expected. The

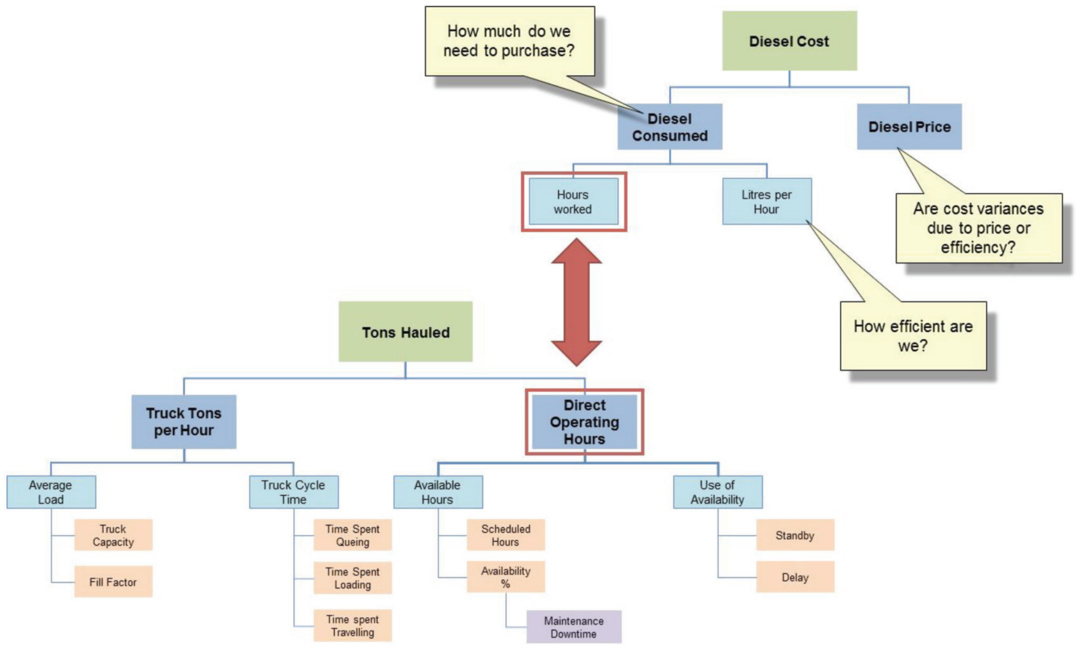

Figure 8. VDT of the hauling activity linked to diesel cost

team members responsible for drilling, blasting, loading, and hauling were included in the discussion.

In summary, some of the outputs from the session were as follows:

a) By understanding the interconnectivity and degree of coupling (i.e. stockpiles or buffers) of the mining activities in the value chain (drill, blast, load, and haul) the team were able to understand that to increase output from mining required management intervention on the bottleneck activity. For example, although the head of drilling often motivates for additional drill rigs to improve drilling capacity, this does not increase the tons hauled as drilling was not the constraint
b) The facilitator demonstrated to the mining department the concept of 'internal capacity' of each activity, which is what that activity can achieve if it operates independently at its current operating parameters. In the context of hauling this is what can be achieved if hauling is not starved of material from loading or is never choked by the crushing activity downstream. Starving and choking cause consequential delays on activities due to the variability in the throughput of each activity in the value chain and result in the overall 'system' delivering a far lower throughput than even the activity with the lowest internal capacity. The team could see that focusing on reducing consequential delays on initially the bottleneck activity and then progressively on all activities could improve the mining throughput by over 15%.
c) The team realized that timing or synchronizing of planned maintenance of critical equipment could reduce consequential downtime significantly, and that they needed to work more closely with engineering to schedule these activities better.
d) The team debated the concept of hauling not tipping directly into the crusher but rather creating a stockpile and double-handling the material into the crusher with a loader. The trucks often queue at the crusher waiting to tip due to tipping time and build-up of material on the grizzly. This results in increased truck cycle times and therefore reduced hauling fleet capacity. Also, the crusher ideally needs a consistent feed without the peak loads it currently experiences. Finance's response is that double handling will cost money. By running this scenario in the VDT the team could see that when the hauling fleet is the constraint, the additional throughput and therefore value creation achieved by the hauling and crushing activities far outweighed the cost of double handling from the new stockpile.
e) The operator availability example from the HR workshop was also explained to the mining team, and how they can work more closely with HR in future in terms of workforce planning.

Session with engineering department

The session with the engineering department was very insightful to the engineering team.

Below are some of the examples of value drivers and discussions that took place in the workshop relating to the hauling activity VDT in Figure 5.

a) The engineering manager stated that his 'KPI is equipment availability for all equipment in the value chain'
b) The facilitator demonstrated in the VDT model that availability should not be his KPI for the following reasons:
   - Even though the availability for most of the equipment was actually very high, the ratio of unplanned maintenance to planned maintenance was disproportionately high (70% unplanned maintenance). Engineering were doing a good job of reacting to breakdowns, doing the unplanned maintenance, and thereby keeping up the availability KPI, but the downtime was having a major impact on the overall value chain throughput for mining. Poor reliability of the hauling fleet was causing consequential

downtimes on the loaders' ability to load. Increased reliability of equipment to reduce variability is a more important value driver than availability. This is achieved by focusing on planned maintenance on the 'right equipment at the right time' as explained below.

- The workshop highlighted to the engineering team that availability on all equipment is not 'worth' the same in terms of value i.e. each hour of availability is not worth the same in terms of value. The availability of the activities or equipment with spare internal capacity relative to the overall value chain throughput is not as critical as the utilization, as this availability is lower than the bottleneck activity or equipment. Therefore, the priority should be planned maintenance on the bottleneck activity to increase its internal capacity and maximize the value chain throughput. The mining activities are dynamic, and changing operating conditions relating to equipment breakdowns, standby, mining layout, travelling times, and material hardness etc. all have an impact on the dynamic system constraint. Therefore a VDT model is a powerful performance management tool to focus engineering maintenance on the most critical equipment to increase its reliability and availability so as to to reduce variability and increase internal capacity. Internal capacity gives an activity an opportunity to catch up if impacted by consequential downtime.

Final session with EXCO

The information from the individual sessions was collated and presented to the GM at the EXCO with all discipline heads.

The GM was very pleased with the outcome and the team commented that this was one of the first initiatives that they had seen that 'really adds value to their lives and focuses their attention on the right things'. They mentioned that they are 'bombarded by initiatives and business intelligence solutions', and all this 'noise' is hiding the real areas they should be focusing on. The VDT prioritizes actions for them.

Conclusions

In summary, this case study was able to demonstrate the following:

- A VDT model of the metrics and value drivers of the individual activities in the full mining value chain is a powerful means of understanding the true impact of decisions made on costs, production, and ultimately value. It exposes the business logic and, even more importantly, integrates all individual disciplines, activities, and variables across the full value chain so that the impact on value can be determined.
- The individual workshop sessions held with the HR, finance, mining, and engineering departments proved to be very insightful and valuable to each discipline as these empowered and showed each of them how they can actually influence business value. The approach utilizing individual workshop sessions also allowed a secure environment for internal discipline discussions.
- The HR department realized that they are not purely an administration function, and that they have direct control of value drivers across the full value chain that impact business value. They committed to making manpower planning sessions about value and not cost.
- The engineering department's focus is on availability, but this is not as important as reliability so as to reduce variability and consequential downtime and prioritizing planned maintenance on the critical bottleneck equipment to increase its internal capacity. Each hour of availability is not equal in value.
- The finance department's fixation with cost management was turned on its head and changed to a value-based assessment. Cost management is critically important but must be done in the context of value. When management ask for a 10% cut in the budget, they must assess this in the context of the drivers that impact cost and, importantly, the impact on production and value.
- The mining department understood the impact of interconnected activities and that the degree of coupling (buffers and stockpiles) between these activities results in consequential downtime due to throughput variability in individual activities. This results in the overall mining value chain delivering far less throughput than the throughput of the bottleneck activity. Mining realized that they could achieve over 15% improvement in throughput from the pit without additional equipment by just focusing on reducing consequential downtime and the internal capacity of the bottleneck activity. Optimizing the shift changeover and the resulting lost operating time could have a major impact.

Acknowledgements

The authors would like to thank the client, project team, and the Cyest Technology team that put in some hard work to build this VDT model of the business and which gave the ability to be able to hold insightful workshop sessions with the individual disciplines.

We would also like to thank the teams from the HR, finance, engineering, and mining departments that made the time available to attend the workshops and for their active engagement to add value to their business.

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Gary Lane

Managing Director, Cyest Technology

Gary Lane graduated with a Bsc Civil Engineering degree in 1990 from WITS University on an Anglo American Scholarship. Gary then spent 10 years working in various project engineering and project management positions within the group companies for New Mining Business, Anglo Technical Department, Debswana Diamond Mining Company and De Beers.

Gary completed an MBA in 2000 through Bond University in Australia and left Anglo American to found Cyest Corporation in 2001 with two colleagues from Monitor Consulting. Gary has built up the mining consulting business that became known as Cyest Analytics which has been involved in strategic mine planning and mechanised mining optimisation for mining client. In January 2014 Gary became the MD of Cyest Technology which focuses on the development and implementation of mine planning and optimisation solutions for the mining Industry globally.

Gary played an important role in the vision and overall leadership of the Syndicated Driven Development Program (SDDP) with Bentley Systems for the New Mining Planning Solution that is jointly being development by Cyest and Bentley and which brings a new paradigm to effective mine planning.

Gary's personal vision is to drive a quantum change in the mining industry by getting them to embrace technology to enhance decision making in mine planning and execution by understand their key value drivers that impacts performance.