# THE DEVELOPMENT AND APPLICATION OF KEY PROFIT DRIVERS IN MINERAL RESOURCE MANAGEMENT

by

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# ABSTRACT

Every mining operation is constantly seeking for new ways to manage a broad range of business variables. Managers across the production chain find themselves torn between the initiatives to reduce costs, balancing throughput and asset utilisation improvements, maintaining product quality, and other similar performance indicators. This they do in their respective areas of responsibility, measuring against their set targets. Herein lies the dilemma: Which operational factors will maximise the profit of the organisation as a whole as opposed to the individual areas. And what is the impact of parameters outside their domains on their performance areas?

Palabora Mining Company has been no exception in this scenario. With time the same issues and operational challenges were presenting itself to the management team. The question had to be asked: Would a fundamentally new approach to viewing the business unearth anything new and useful to take this remarkable company to new heights? This study was launched to challenge the views of business and to offer answers to the above dilemma.

The study has shown a remarkable degree of interlinkedness between production variables across the production chain. For instance, the mineralogy and petrology of the rock mined had strong effects in the milling, flotation and even smelting processes, and the status of the metal market price conditions offered exciting options to operational managers, provided the relationships are understood. Using an integrated model the magnitude and nature of interrelationships between the drivers of performance are explained. As a result it could provide the capability to "play off" costs against benefits for operating decisions. For example: How long should one keep the open pit mine operational and should it be decommissioned at the same or at a different time as the downstream units?

The integrated nature of the business model clearly showed that to reach optimal performance for the whole company, decision-makers across the production chain need to plan collaboratively. It was evident that the powerful modelling approach will loose its effectiveness if the organisational thinking is not changed to a collective one. The model therefore, could only be effective if it is embedded into the planning and monitoring business cycles.

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# 1 Introduction

As has been the case with most other industries, the information and now virtual age has also dawned upon the commodities industry. Its impact is two-fold, firstly, on the internal value chain of organisations and secondly, extending the value chain beyond the borders of the organisation. Therefore, apart from the effects of globalisation developments like Commodity Exchanges and E-commerce, these changes are impacting on the very assumptions on which mining operations are basing their decisions. Maximising throughput volume, cut-off grade policies and optimization algorithms might be based on outdated strategic assumptions and hence, requires one to revisit them with an open mind.

It is mainly the former of the two, the intra-organisational impact that will be the focus of this study, not neglecting considerations that derive from the impact of various external factors like economic cycles, current and future demand-supply situations, and market-pricing conditions. The view is taken that a fundamental improvement in the understanding of the interrelationships between ore reserve and the complete downstream value chain is required. This view is the essence of an overall management philosophy for natural resource beneficiating companies, known as Mineral Resource Management. A definition formulated during the project is:

*Mineral Resource Management is an overall management philosophy that aims to optimise the shareholder value of an ore beneficiation site through the alignment of the ore resource characteristics, process flow configurations, final product mix, as well as people, business processes and information, over the full life of the natural (ore) reserve.*

The enabler of such alignment is the *horizontal integration* of the complete value chain and the *vertical alignment* of strategy and policies with day-to-day execution. At the heart of the integration sits *an integrated, hierarchical, business factor model in which the relationships between profit drivers are quantified and structured.*

Fundamental to, and enabling organisations to survive among all these changes, is the concept of integrated supply chain management, which will be described in further detail in the ensuing sections. Integration here refers not only to the threading together of business processes throughout the value chain through technology and business

process redesign, but also the integration of the way people plan and execute operational plans. The management of organisational change is therefore a key process in achieving integration.

Every additional level of business integration brings added challenges and benefits, and is enabled by the former levels of integration. *Industry will find itself competing with whatever competitive edge it has secured through integration and not so much the level of integration it has mastered.* It is therefore not the integration *per se*, but the logic behind it that unlocks the benefits to organisations. And it is this logic, and the approach to ensure the logic is captured, that the Mineral Resource Management philosophy seeks to address.

Although integration is not a new concept to the mining industry, it has been notoriously difficult to manage the process of integration without adequate systems to ensure that the essential logic is retained. The term "systems" used here refers to more than just information systems because it includes specific integrated business processes as well as the way that people think about and execute them.

The intention of this study is to illustrate the challenges and obstacles, as well as the approach and techniques required in establishing and exploiting a mining business model built around a profit driver model. This study will not explore the width and the depth of the Mineral Resource Management philosophy. As such, Information Technology and Enterprise Management Systems, Change Management and Methodologies will be mentioned but not covered in full. It aims to document the finer nuances of profit driver modelling which highlights and quantifies the relationships among variables from operating to strategic levels.

Although the study has a strong profit focus and business orientation, it does not underestimate the impact of the mineralogical make-up of the ore mined in downstream processes, and the considerations given in the modelling process of those relationships. Lack of outright proof of a relationship, the multi-dimensionality of process parameters and the variability of the behaviour of processes make it difficult, if not impossible, to forecast the direct, single impact of minerals on performances. It will be attempted to show the relationships that develop among the mineral make-up, the metals, and the chemical elements throughout the value chain.

# 2 Problem Statement

## 2.1 Background of the mining site under investigation

The study took place at Palabora Mining Company, and commenced in April 1994 running towards the end of 1995. The one deliverable was a profit driver model, also called the Focus® model after the software modelling tool used. Another deliverable that followed was a revised strategic planning process, as described in Section 6.

The mine was at that time an open-pit copper mine that was nearing the end of its life and faced the challenge of either closing down operations by the year 2003 or establishing an underground mine to extend the life of the mine. Feasibility studies for the underground mine were still underway at the time of this project. Initial studies indicated that chances were slim for the underground mine to obtain the approval of the RTZ (Now Rio Tinto) executive board (PUMP feedback, 1994).

The very low-grade copper ore (average 0.6%) is contained in an ore body that is a carbonatitic core of a complex ultramafic intrusion in granite gneiss (Wilson, 1998). Around the carbonatitic core are concentric layers of phoscorite (or Foskorite, named after the adjacent phosphate mine Foskor), pyroxene pegmatoid and micaceous pyroxenite. This complex ore body proved to be viable through the extraction of copper, phosphate, magnetite, uranothorianite, zirconia, and vermiculite. By-products sales also contributed to the low-grade ore body becoming quite profitable (Palabora Marketing Department Statistics, 1996).

The mine produced copper concentrate, anodes and cathodes, various grades of magnetite, 5 grades of vermiculite and various grades of zirconium concentrates and chemicals, uranium oxide, as well as a range of chemical salts during the refining processes. Apart from the run of mine (ROM), final slurry tailing streams as well as final effluents, all products and by-products could be economically sold as-is.

As can be seen in the process flow diagram in section 5.1.1, the main production processes comprised the open pit mine, crushing, screening, milling and

concentrating, smelting and refining steps. In between every production step were one or more stockpiles or buffers, which are fundamental to the optimization of the business as a whole. Although the by-products were very much part of the optimization model, the productions steps are not of noteworthy importance worth mentioning here.

Sales took place through a sales and marketing department locally as well as subsidiaries and agents in the UK, the USA, Japan and Australia. As these activities are part of the value chain, the impacts of these distribution channels had to be understood and captured within the model, as will become clear in the next section.

## 2.2 Various specific aspects of the problem situation

The mine has been operating since 1967, which was the first full production year (Pottinger, 1990). It had been in a mature state for approximately 20 to 25 years at that time and had been approaching the end of open-pit mine life. As a subsidiary of RTZ (Rio Tinto Zinc), it had earned a great reputation as a mine that could be profitable on an ore body with a head grade of an average of 0.6% – 0.8%Cu, when mines in the Copper Belt in Zambia and Zimbabwe have had average tailing grades of 1% copper, i.e. substantially higher than the Palabora head grade (Robinson, 2000). The mine's tailings of 0.06% to 0.09% appears unreal in benchmarks with other mines.

Apart from the political and social transition that the country found itself in during the eighties and nineties, the copper metals market had undergone sudden changes that had upset the metal price (LME statistics, 1994-5). The empirical inverse relationship between the copper price and world stock levels did not apply anymore, indeed, this measure did not apply to that particular period anyway (Project team investigation, 1994-5). In addition, the profit margin of copper had shrunk during the early nineties signaling the need for the company to revisit the throughput and cost plans to avoid severe cutbacks. This situation did not augur well for the continuation

with an underground mine promising inherently higher cost structures (PUMP team interview, 1994).

Apart from the abovementioned environmental factors, and as a result of the study, other contributing factors were also becoming apparent. Herewith an overview of the more important factors, starting with an overview of mineralisation:

- The complexity of the copper mineralisation is such that with a constant throughput rate the millability, flotability and smeltability varies considerably (Steynberg, 1984). The generally accepted relationships of the mineral makeup today are as follows:

  o **Millability:** Phlogopite, magnetite and dolerite are three minerals that specifically impact on the millability of the ore (Steynberg, 1996). The influence of phlogopite, a micaceous mineral, had been recognised as a possibility but due to the low and spurious presence within the carbonatitic ores (it was certainly a factor at the phosphate processing plants at Foskor when processing phoscorite with its higher levels of phlogopite) attention has turned towards magnetite (Joubert, 1992). This iron-bearing mineral became first priority due to a 25% presence in the ore (although only 15% of the total copper is associated with this fraction) (Steynberg, 1984:2). To limit the copper losses in the coarse and fine fractions of the flotation feed, every effort has been made to produce a narrow size distribution. Due to magnetite's relative high specific gravity of 5.1 kg/l (and hardness of 6.0 on the Mohs scale) (Taggart, 1945), it tends to recycle through the cyclone underflow back to the mills, and as it starts building up in the mills, inhibits the grinding process (Joubert, 1992).

  Dolerite, originating from the dykes running across the ore body, is present in the ore feed in a range of 2% to 10%, turning out in recent years to be an equally inhibitive rock in the crushing and grinding circuits. Initial estimates that needed further research indicated that every 1% of dolerite reduces the mill throughput by between 3% and 4% of good ore in a conventional milling circuit. In the autogenous

milling circuits it acts as a grinding medium improving the milling efficiency and hence does not have the negative impact on the crushing circuit (Interviews with metallurgists, 1994). The actual replacement factor in the downstream milling was guesswork at best.

o **Flotability:** With five different copper minerals contained in the feed, of which the flotation properties vary from fast to slow floating, the residence time (in the flotation cells) and the reagent combination is of utmost importance (Steynberg, 1984:24). The dilemma is that the operational reagent dosage control is at best a black art and is dosed at an average rate aimed at an average copper mineral content. The residence time of 20 minutes seemed optimal at the time (various internal research reports); the recovery impact of residence time was not clear and therefore not useful for modelling at the time.

The matter of flotability enters a new level of complexity when the various copper minerals are considered. Carbonatitic ores (a basic ore) prohibits the acidifying of the slurries to anything lower than a pH of 6.0 to 7.0, at which point copper recovery starts improving further, especially of valeriite; one is therefore left in a lower floating pH domain (Joubert, 1992). Valeriite is a dull, bronze-coloured, soft (1 on Mohs scale) and platy mineral that has extremely poor flotation properties in the above pH=7 domain (Steynberg, 1984). It causes tailings grades to vary hugely as the valeriite level varies between 1.8% and 8.1% between the various rock types in the carbonatitic ores specifically treated by the Palabora plant. It has been determined that valeriite may be responsible for as much as 60% of the copper losses through tailings (Steynberg, 1984:17).

The discrepancy between valeriite's low presence and the high amount of losses was also investigated during the study. This was later confirmed by Jan Joubert, resident mineralogist (1992). It turned out that due to valeriite being the youngest copper mineral among the other copper bearing minerals (chalcocite ($Cu_2S$ - 79.9%Cu), chalcopyrite ($CuFeS_2$ – 34.6%Cu), bornite ($Cu_5FeS_4$ – 63.3%Cu), and

some cubanite and mooihoekite), it is often seen as intergrown with the other copper minerals (Steynberg, 1984). Breakage during crushing and milling results in the more flotable minerals being coated with the poor floating mineral, causing poor contact angles with the flotation bubbles. Biswas and Davenport (1980:32) confirmed this as a general phenomenon in flotation practices.

o **Smeltability:** Further downstream, the smelter receives the copper concentrates with varying mineralogical contents. As with the two previous processes, the varying mineral make-up also affects the smelter performance due to, among others, the position on the $Cu_2S$-FeS equilibrium phase diagram (Biswas and Davenport, 1980:84 as obtained from Schlegel and Schueller, 1952). Other phase diagrams like the Cu-Fe-S (Biswas and Davenport, 1980:84, obtained from Krivsky and Schuhmann, 1957) illustrate the complex systems that underpin this varying smeltability. The operational decision-making is made exceptionally difficult without the measuring mechanisms to provide the information in time before the decisions are required. An alternative to such a predictive mechanism is to "push" the concentrate compositions further into the stable areas of the phase diagrams by blending in other minerals, like quartz with the flux to facilitate the separation of slag and matte in both the smelter and converter stages (Biswas and Davenport, 1980:94). These kinds of additions come at a cost and have to be carefully offset against the benefits derived by doing so. Test work at Palabora during the early nineties was successful and blending in quartz became common practice.

It is at this point in the process-value chain that the mineral content analysis would mean much to smelting operations people, should one have the means to determine this in time (and at reasonable cost) to have the information ready in time to influence decisions on the smelter floor.

These spin-offs of the mineralogy for the business are as important to the optimization of the complete value chain as are the broader economic

principles. The introduction of an integrated information framework that allows the combination of the mineral impacts with economic models opens up new opportunities with wide-ranging profit impacts, as this study will endeavour to show.

Experience has shown that where mineralogical information is available to operations managers, it has been used for explaining poor process performances rather than for controlling and improving metallurgical processes. In addition, as are the case with mature organisations running into profit margin pressure, research and development seem to be terminated instead of refocused towards more appropriate aspects of the business. Perhaps these research laboratories should instead be transformed into a powerhouse for more modern multi-disciplinary improvement initiatives? The project subject to this report has demonstrated the value of applying the principles of Mineral Resource Management and could be the new form of research laboratory.

- It should be obvious that when the minerals have been transformed into a metal and lost their identity, they have not lost their impact on the downstream processes. Surely the combination of chemical elements they carry into the value-chain must continue to exert subtle, though wide-ranging impacts downstream. A few simple examples are:

  o As explained above, **dolerite and magnetite** impact on millability, which in turn, impacts on flotability (Steynberg, 1996). The magnetite remaining in the copper concentrate then impacts on the smelting process as it reports to the "bottoms", which are discarded later, in the reverberatory furnace (Daily operations reports).

  o In a similar way the **copper mineralisation blend** determines the rate of smelting as well as the matte grade, which in turn determines the converting and fire refining cycle times (Van den Heever, 1975). The level of sulphur in the **sulphides** has a considerable impact on the volume of slag formed, the exothermic heat generated as well as the concentration of the off-gas to the acid producing plant (Biswas and

Davenport, 1980:87).

o The impact of certain chemical elements in the ore, like **nickel** and **silver**, for instance, on electro-refining is just starting to become clear and will be discussed later in this document (Internal refinery performance study; 1993).

Moving on to factors other than the mineralogical, one also compounds the challenges to mining businesses in general, and in some cases particular challenges were identified in the Assessment Phase of the project at Palabora:

- It is common knowledge that, on a global basis, the **rate of change** (e.g. globalisation, E-commerce) in the business world towards the end of the 20th century had increased tremendously. *This raised the question as to whether the traditional approach to strategic planning could still be adequate since the rate of change had to be matched by an increased regularity of strategic planning.* Traditional strategic planning was done on an annual basis with some translation and communication of the strategic actions to the operations.

- It is obvious that the **complexity of businesses** had also increased with the increased rate of change and the increased availability of information. Customers and subsidiaries were inundating the marketing and sales department with calls to establish the latest state of product availability (Marketing department statistics, 1996). Business processes were not bound by the boundaries of the enterprise anymore but extended across the complete supply chain - from suppliers to the plant through to the customers, irrespective of distance and country borders. The company had to plan throughout the full supply chain and had to do so more often, without the support of an integrated information system. Keeping track of stock levels at the plant, in transit and consignment stocks became a complex, stressful operation (Marketing Management System development project for Rio Tinto SA, 1996:7).

- The more complex a business is, the more critical it becomes to understand

the **value that each step in the process adds** and find ways to eradicate the non-Value-adding steps and establish sustainability within the rest. This is one of the core motivations for formulating Mineral Resource Management as a new discipline since belief systems stifle the ability of the organisation to optimise the complete supply chain. Traditional views of product and by-product accounting in complex process streams are one of these beliefs, often supported by the absence of product costing practices (Personal interview with G. Makin, PMC Financial Manager, 1995). A poor understanding of the interrelationships of variables and the magnitude of the interrelationships within variable processes is another. It appeared from interviews that "rules-of-thumb" are fixed within a context, which, as the context changes, are not revisited and adjusted according to new circumstances (Focus Project Study outcome, 1995).

- Palabora had **both commodity and low-volume** production plants, as well as **mature and immature commodity streams**. The streams require different approaches to ensure success in the long term. The copper stream represents a mature product which required little or no further research and development whilst the other, like vermiculite, does; the one had a mature customer base whilst the other did not, and so on. This is typical of mine sites and should be recognized when organisational design is considered. The critical question to be answered would be whether the benefits would not outweigh the cost of some overhead duplication. In other words, would the cost of operating two separate business entities be more profitable than the one combined business? This seems like a no-brainer but becomes more difficult when one has to consider whether that would apply today and in the future? Is it not logical that the immature product will grow better within an innovative environment, as opposed to the maintenance-oriented environment required by the mature product?

- **Silo thinking** in business planning and optimization at Palabora appeared entrenched - mining personnel were still planning and optimizing locally within their areas of control, passing on their completed mine plans to the rest of the mine as a resource for their planning (Focus Project Assessment Phase

outcome, 1994). This, as opposed to the principles of Mineral Resource Management, which assert that the impacts of ore body morphologies and geology are not the only determinants of a profitable mine. Mine planning has to be done in line with the downstream capacity, product supply/demand situations; optimal product mixes as well as distribution constraints and opportunities. This has to be done within the context of the complete life of mine. The critical issue is that the planning is not just a numerical exercise but ought to be a joint, interactive process with the aim to educate, align and focus production and support teams (Mineral Resource Management, 2000).

Planning separately and then combining the plans will not only extend the planning period but will also decouple fundamental relationships that drive the performance of the organisation. Take an example from Palabora: planning in the concentrator aimed at maximum recovery, which suggests that, the lower the copper concentrates grade the better. A corollary to that planning parameter though, is that the lower the concentrate grade feed to the reverberatory furnace, the less the metal output. Although this sounds trivial at first, planning separately might cost the company dearly. Should the reverberatory furnace be the bottleneck, which it was at the time, it might be better to forfeit recovery for a higher metal output. Joint planning will overcome this problem; even more so when it is considered that the mineral make-up of the concentrate might allow for specific kinds of concentrates to have lower grades due to a higher smeltability (Steynberg, 1984; Joubert, 1992).

- **The tiers of IT systems** (i.e. Process Control, Cost accounting and Corporate reporting) were not integrated at Palabora and information was therefore disjointed (Focus Project Assessment Phase outcome, 1994). Lower level data systems required manual summary and transfer of information to higher-level tactical systems. This was repeated in the transfer between tactical and strategic information layers. Attempts to develop some business intelligence around strategic issues had been constrained by nonintegrated information systems.

In summary, although economical, life of mine and organisational factors are probably

most important for the strategic planning process, the importance of taking mineralogical aspects into account stands out as fundamental to the process. All the above factors are probably overshadowed by the impact that resistance to change has on organisations. *The challenge here is to accept contemporary views of corporate valuation, accounting and resource management. It is more often than not the single-most challenging hurdle to overcome when launching into a Mineral Resource Management renewal drive* (Thomas and Sylvester, 1995). Before any organisation will be able to absorb the principles of defining a profit driver model, it will have to accept that long-standing policies, managerial approaches or thinking will be challenged. These "policy constraints" as Goldratt and Cox (1992) describes them, when they exist, must be removed before physical constraints can be addressed effectively.

The success of a profit driver-modelling program hinges on the organisation's ability to think collectively. That, in turn, depends on whether its executive has developed this ability in the first place. This is what constitutes a "learning organisation", as defined by Peter Senge (1994). Learning organisations are ones that can learn from experiences and then swiftly adapt to ever-increasing environmental changes.

Developing new advanced approaches to strategic business modelling and execution seems necessary. Applying the modelling approach that was adapted from McKinsey Consulting had been used with this study (Thomas and Sylvester, 1993) and was aimed at addressing the abovementioned issues.

# 3  An Overview of Relevant Concepts

Before launching into the project approach, one has to consider the importance of the statement made at the end of the previous section, relating to the challenging business-as-usual thinking and longstanding policies. It is not so much that the thinking is considered to be wrong or that the policies are challenged because they are flawed, but rather to identify and understand the implications of these policies, rules and agreed-upon conventions and compare them with two alternative business approaches.

The following paragraphs aim to explain some of the terms and concepts referred to in this study. Starting off with the Mckinsey's organisational change model (Waterman, 1979) to explain the context from which the scope has evolved. This is followed by a discussion on supply chain management, which is again the broader concept within which the internal value chain of the organisation is embedded. The concept of bottlenecks as it specifically relates to the mining industry is then considered.

The essence of what determines the bottlenecks, namely the ore and its characteristics, and its effect on the downstream processes will be covered in more detail in later sections. Other important factors, imposing a different kind of constraint, are commodity economics and the way that organisations look at data and report on them - these will also be discussed.

The approach to management accounting is touched upon then, not to cover what it is and exactly how it works, but rather to explain why this approach suited the study best. A short venture into the pricing of metals with particular attention to the market situation called backwardation as it is of particular relevance to this study. A powerful way of looking at the wealth creation within an organisation, and of managing personnel performance, is a concept, introduced by Stewart and Stern (1990), referred to as Economic Value-add®. The concept will be covered to an

adequate level to gain an understanding of the results of an assessment of the company weal'th creation profile over that time, using the Focus® model.

The next logical step is then to obtain some background on FOCUS®, the modelling tool used throughout the study, followed by the concepts of building information structures that allow for a powerful analysis and reporting on best alternatives of doing business. Lastly, one of the outputs of the study is a key profit driver set which is the umbilical cord between the strategy and the actions of the people executing the plans derived from the strategies.

## 3.1 The McKinsey 7-S Model

Research from the late 80's to the early 90's by Waterman (1979) on organisational change has led to a revision of how people think about what aligns an organisation to the better of the organisation. The tradition was then and is sadly, still today, to change the structure as this will change the way people work. Certainly one cannot expect this change really to make organisations perform substantially better if people do not change the way they think and go about doing business? Waterman suggested that the complete organisational picture with all its facets should be taken into consideration to be able successfully to introduce a change.

How should one view the organisation and what are the implications of such a view with respect to transforming it and its ways of doing business? Again, it turns out to be a matter of integration of various aspects of the organisation into a whole, as was discussed in Section 1 of this study. This time integration is around **Structure**, **strategy**, and **systems** – or the "hard" S's on the one hand and **skills**, **shared values**, **staff** and (management) **style** – or the "soft" S's on the other hand. The diagram illustrates the model:
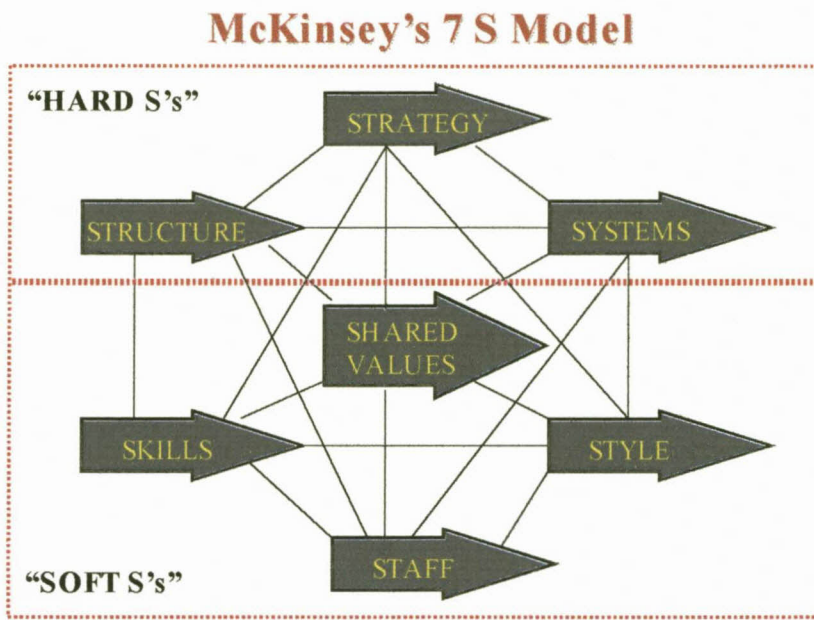
# McKinsey's 7 S Model



**Figure 3.1 The McKinsey 7-S model (after Waterman, 1979)**

Waterman points out three important aspects of this figure, namely that:

- A **multiplicity of factors** exist which influence the ability of an organisation to change and which would be necessary to consider so that change may be effected. One of those factors might be the focal point, but the others do exist and cannot be ignored during an intervention in an organisation.

- The factors are **interconnected** and will collectively resist change, or offer opportunities indirectly to reinforce change in another area.

- The diagram is circular and **not hierarchical**; no single factor is more important than the other. Also a factor that is important in one situation might not be in another. A company on the verge of bankruptcy will probably be focusing on strategy, whereas the one with industrial relations problems might be more interested in shared values, staffing, the correct management style and so on.

The 7-S model is meant to be a diagnostic framework to establish which factor(s) require change and which of the others should be addressed to support the change dynamics once they are put into place.

The brief for this study excluded any organisational change and hence the focus remained on the three "hard" S's namely, strategy, structure and systems. The wisdom of the brief, or the lack thereof, will be discussed further later in this manuscript.

## 3.2 Supply Chain Management

Michael Porter (1990) has been instrumental in developing the concept of a **value chain**, which he used as a diagnostic tool for assessing competitive advantage, and finding ways to enhance it. It divides a business into discrete activities to distinguish between core and supporting business functions. Core functions are those, which the business itself has to execute to stay in business and to remain competitive. All the other functions are supportive of the core functions and can, and often should, not be an internal business function.
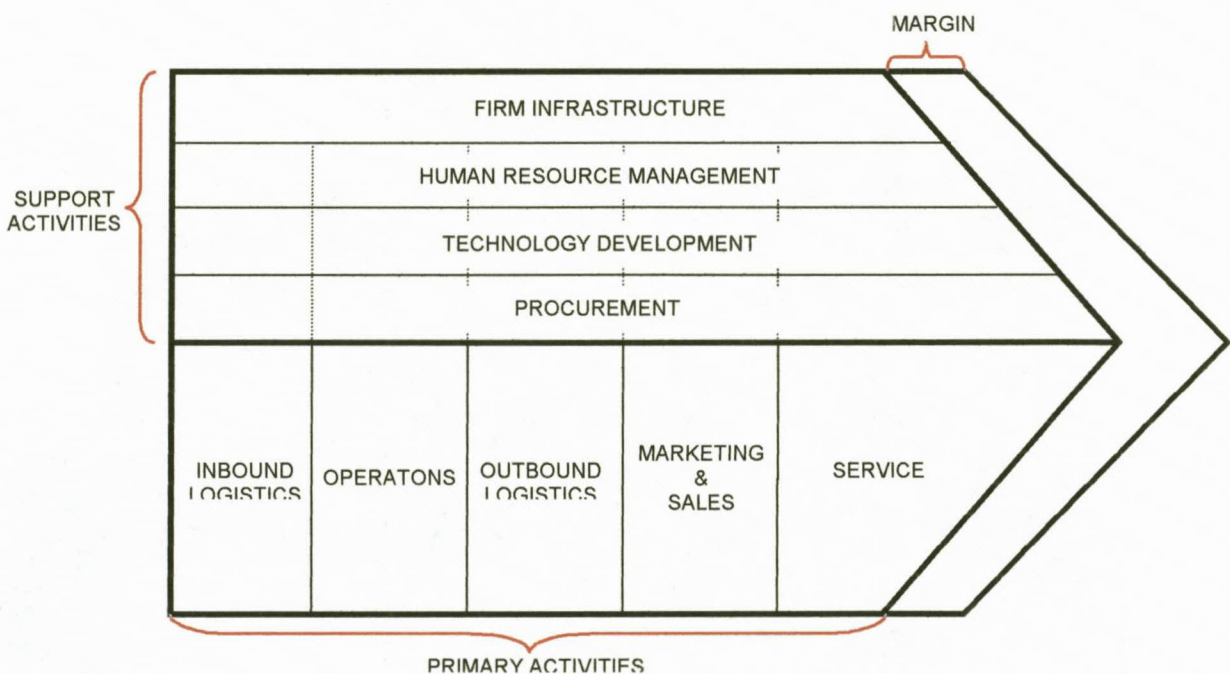


**Figure 3.2a. An Internal Company Value Chain  (Porter, 1985:37)**

It is this value chain that becomes a building block of a **supply chain**. Supply chain management takes a broader look as it considers the suppliers of raw materials, consumables and services as well as the customers as extensions of the internal core functions.
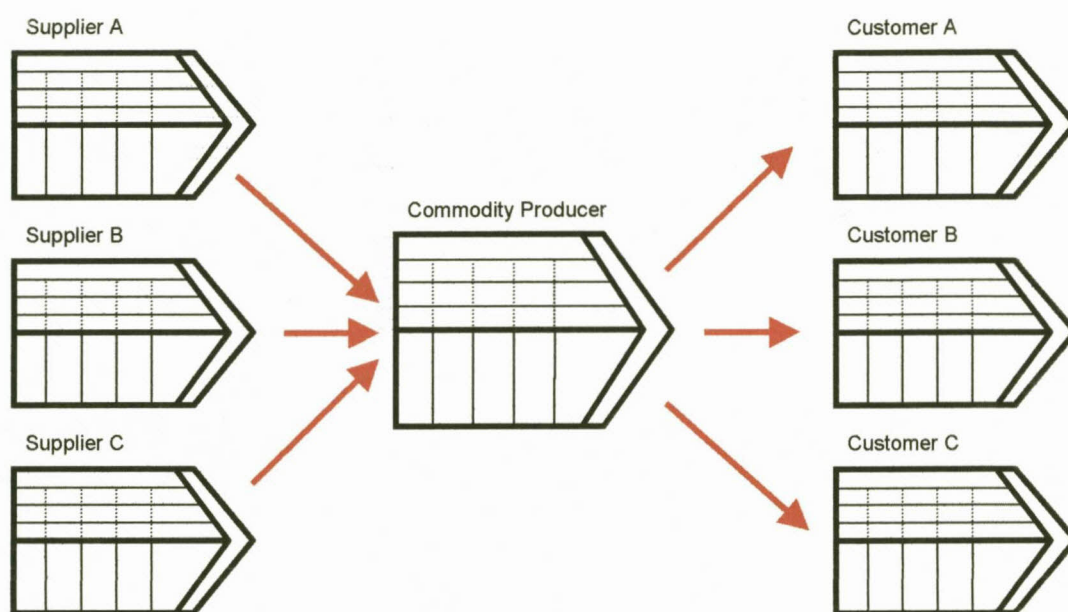


**Figure 3.2b. Extending the value chain into a supply chain (Adapted from Porter, 1985:37)**

It is evident that any single profitable organisation can, and will destroy itself if it does not ensure that up- or downstream processes do not destroy the hard-earned profitability through inefficiencies. The objective of this supply chain is to ensure that all supply chain partners gain some benefit from synchronising the flow of materials, consumables and products among them.

Participants in a supply chain have positioned themselves strategically for growth and provided they add value in the flow of products and materials, protect their future business. It provides various opportunities to participants:

- It allows them to **integrate** their business processes between the participants of the supply chain. Orders, invoices, stock reports and delivery notes can be exchanged electronically and thereby reducing administrative burden, costs

and most importantly ensure clear and up-to-date communication. It is even possible now to have the business systems among business partners set up automatically to make payments and complete journal entries.

- Integration renders the complete supply chain visible to all participants, enabling them to **optimise** their products and services. They can exchange data with each other upon request to synchronise material and product movements between each other. This they do as they can now minimise waste, deliver the right product at the right place and on time. Costs are driven down and profits can be improved.

- Recent technological developments have made it possible for the optimisation to be taken further as supply chain participants are now starting to **plan collaboratively**. The supply chain participants now become partners to optimise around bottlenecks in the delivery chain. Exchanging data is enhanced to information sharing as all the supply chain data becomes accessible to participants in a central electronic planning table. An example is Richards Bay Coal Terminal where the co-owners of a port loading facility swap load-out allocations to ensure minimal joint stoppage and hence improve the overall utilisation of the facility. Higher throughput means that apart from higher sales revenue, the unit costs for the facility are reduced and all participants benefit.

How does the above relate to the study at hand? It has been stated above that a profitable organisation can destroy its wealth in an inefficient supply chain. To become profitable the same principles that have been applied in describing the supply chain above should also be applied within the value chain (or internal supply chain) of the organisation. Matching these principles on a point for point basis:

- **Integration** of business processes within the organisation eliminates the duplication of work and hence, cost. This is easier said than done, as the mining divisions within organisations are often autonomous and operate their own workshops, stores and specialist mine planning systems. This is probably, and also partly, due to the belief that as long as the run-of-mine stockpiles are full and costs are kept at bay, the mining operation is doing

well. This study, as is the Mineral Resource Management philosophy, aims to show that a completely integrated planning system will unlock enormous potential for the business as a whole.

- Integrating the complete value chain of the business makes it visible to all employees and so that overall **optimisation** takes place. The real constraints will become visible and local optima will start giving way to an optimised whole business process chain. Information is then exchanged upon request between participants in order to synchronise product movements between each other. Planning and optimisation take place collaboratively within the organisation requiring cross-functional teams to plan together.

- Only with the above in place can true **collaboration** take place where the organisation now focuses on supporting the bottleneck in the value chain with non-constrained resource. The interrelationships between variables throughout the value chain become obvious and hence manageable. No longer is it somebody else's problem if the corporate bottleneck is in a different department.

One could think that the integration of the internal supply chain should come before integrating the complete supply chain. Behind this reasoning is the gut-feel that poorly integrated organisations cannot be a reliable supplier to downstream supply chain partners. After all, how does one build a smooth supply chain if the elements within it are not predictable?

If we consider the behaviour of a supply chain where one needs a steady flow, smoothing material or product deliveries to downstream partners, and then to an unpredictable producer will definitely be hampered by irregular deliveries. Considering the upstream side of such an organisation, high internal stock levels will also prevail, as the variation in its demand for raw materials will be larger than would be the case with an integrated organisation. Although it is conceivable that the upstream demand from suppliers can still be fairly regular in such a business, due to buffering, the supply chain partner will be less profitable and hence, introduce more risk to the whole supply chain.

The precedence of internal integration to the rest of the supply chain does not mean that the organisation's internal value chain needs to be perfect before proceeding with external integration as one never knows when the one is far enough to proceed with the other. Goldratt (1990) states that the essence of achieving an optimised throughput is to find the constraint in the supply chain and exploit it. As one does so and breaks the constraint, another will appear elsewhere. In the same way the constraint will vary between the internal and external supply chain.

Is supply chain management in the mining industry different to any other supply chain in say the manufacturing industry? On face value it appears similar to other industries - *until one recognises the impact that the ore reserve characteristics have on the downstream processes.* Ore characteristics, such as mineralogical content, petrology; geology, etc. induce throughput bottlenecks (constraints) downstream in the value chain, and in such a way that the constraint will shift from time to time. Electricity, reagent and grinding media consumption can vary extensively with some ores, together with the production outputs and product quality. *The difference in the mining industry therefore lies in the ore-driven variation in throughput and product quality, which other industries do not have.*

Testimony to this difference is that specification tolerances within most mining products will exceed the allowed tolerances for automotive, chemical and pharmaceutical industries by orders of magnitude. Commodities are therefore sold in various grades with penalties and bonuses for specific constituents in the products, whereas in the manufacturing industry the drive is towards zero tolerance.

Understanding this unique challenge to mining organisations is what drives the continuous search for planning within a dearth of varying conditions. Recognising the need for connectivity between the ore reserve characteristics and the downstream processes and product blend in the business planning models is fundamental to a successful mining supply chain. (P.G. Laurens – unpublished research, 2000)

## 3.3 Bottleneck – the mining value chain constraint

The Theory of Constraints was coined and made what it is today by and Goldratt and his associates, starting from within the discrete manufacturing industry, established a new way of thinking about what makes an organisation achieve its goals. They define a constraint (Fox and Goldratt, 1988 [TOC Journal Vol. 1, No2:9]) as:

"A system's **constraint** is anything that limits the system from achieving higher performances versus its goal."

Pointing out the need for defining the terms "system" and "goal" before the definition makes sense, he restricts the term "system" for this purpose to "organisation", and defines "goal" as:

"The goal of Western industrial and service organisations is to make more money now **as well as** into the future"

It is the word "anything" in the definition of a constraint that seems to introduce a troublesome multi-dimensionality into the world of Mineral Resource Management. Consider, for instance, the 7-S model described in the beginning of this section. One could say that every one of the seven elements is a constraining dimension to optimising throughput and profit for an organisation. This would leave any consultant with the impossible task of resolving various constraints. Goldratt fortunately points out that these are not constraints but <u>necessary conditions</u>. The word "anything" therefore specifically refers to the core value-chain components with a strong focus on *throughput*.

Key measurements, or key profit drivers, underpin the Theory of Constraints or in mining lingo, the definition of bottlenecks. Fox and Goldratt (1988) defined three core measurements namely THROUGHPUT, INVENTORY and OPERATING EXPENSE. These three measurements form the pillars of the measuring system, as covered in the next section on the approach to management accounting.

Apart from the strong discrete nature of Goldratt's work, it does seem to fall short on the latter part of his definition i.e. "...(make money now) and in the future" to make such earnings useful for the mining and minerals industry. What became evident during this study is the importance of understanding how both longer-term and short-term views of "making money", as Goldratt puts it, should be taken into account when modelling a mining business. It was clear that the short-term view emphasized the money made for this financial reporting year, whereas the long-term view is needed to achieve the organisation's **real** goal, which is to **generate wealth over the life of mine**. His own words ring true here when he remarks: "It should be emphasized that an "*optimum*" is really nothing but another name for "*tolerable compromise*".

Another fundamentally applicable aspect in his work for the mining and minerals industry is to further distinguish between constraints to assist in clarifying whether the constraint is short, medium or long term. As shown in section 5 below, relaxing a short term goal might very well remove a constraint that impacts on a long-term goal, as the one is aiming at improving a performance *as defined by financial reporting standards* whilst the other is aiming to improve the performance of *a wealth-creation goal* which falls outside the limited vision of financial reporting systems.

The Goldratt approach (Fox and Goldratt, 1988) is to construct the problem in a way that clarifies the underlying conflict, which is what needs to be resolved, as shown in figure 3.3.

Different teams in the organisation will interpret the organisational objectives differently. Corporate planning might feel strongly about varying the milling rate in line with market conditions and the status of inventory in the company, whereas the operations personnel are chasing targets and wants to maximise throughput to make up for earlier unplanned stoppages. The conflict among the assumptions of the respective teams is clear. Goldratt's approach will require one to investigate the underlying assumptions and resolve the erroneous ones.

**Objectives**          **Requirement**
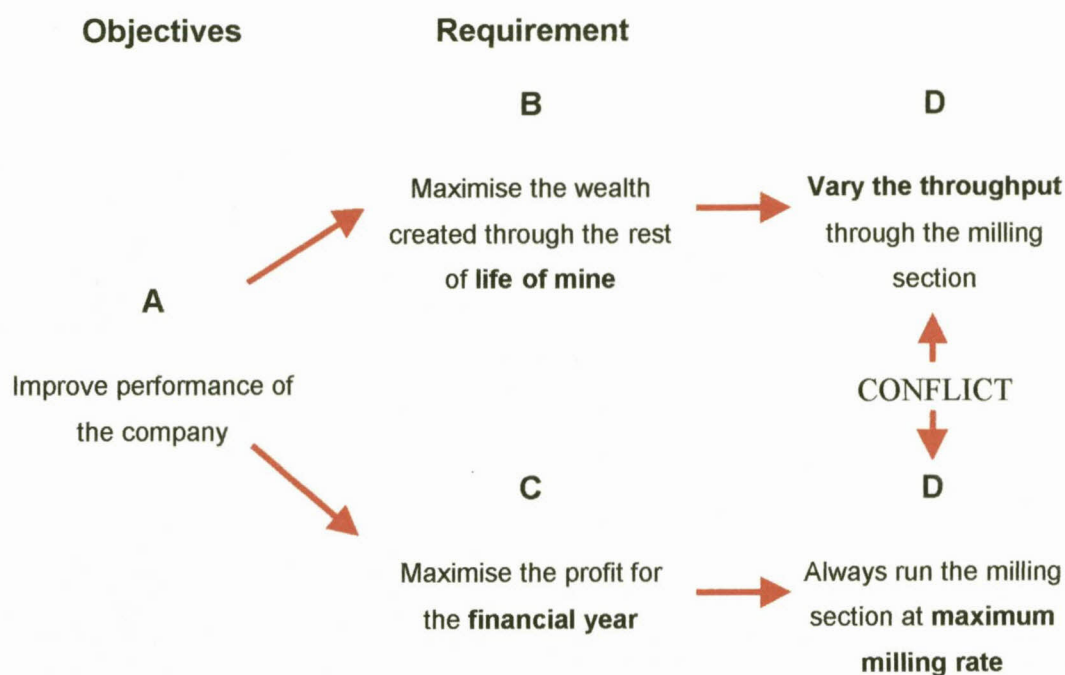


Figure 3.3 Modelling conflicting objectives from the same strategy (Adapted from Goldratt, 1998)

The approach used in this study is similar in as much as it searches for the alternatives to resolve a constraint. The alternatives are modelled in numerical terms with the aim of **clarifying which alternative is best at the time and monitoring the status of the alternatives as the conditions vary** as opposed to **resolving the underlying assumptions and conflicts** in the organisation. The Goldratt approach therefore would be more appropriate as an organisational change aid to be used <u>before</u> the actual numerical modelling takes place and when tactical conflicts arise.

## 3.4  The Focus® modelling approach

The Mitchell Madison Group (or MMG for short) (1997) made a strong case for CEOs and their teams to reflect upon what exactly it is they see when they look at

their traditional corporate reports. They should consider whether it can really help them improve the profitability of their businesses and if so, how.

The MMG (1997) maintained that the standard accounting framework of performance generally used for decision-making **limits** the areas of improvement focus. The traditional decision framework appears as follows:
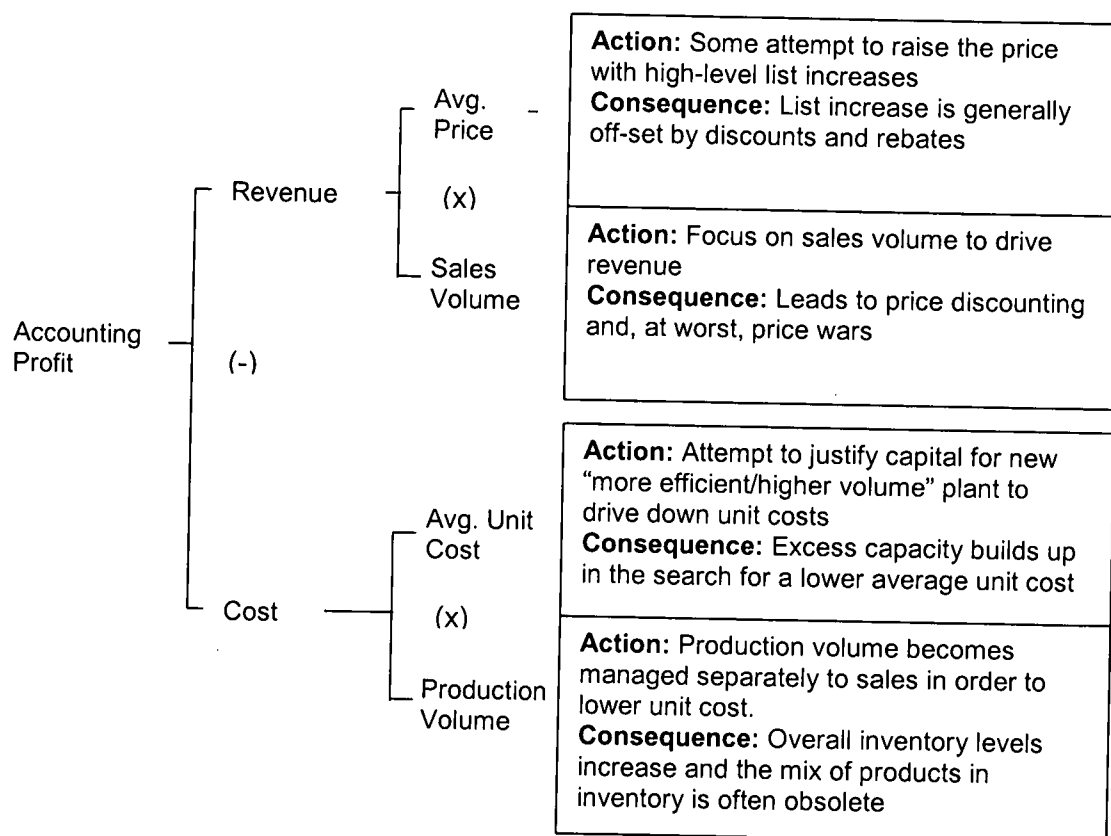


**Figure 3.4a    The traditional reporting and decision framework: (Mitchell Madison Group, 1997)**

Although the traditional framework does show the interconnectedness required for sound modelling, depth is lacking, leaving management teams with a too simplistic view of the profit drivers for the business. Another dilemma with the structure is the averaging out of prices and unit costs, an activity that so often destroys valuable information about which products and costs, individually, should be leveraged for

bottom line benefits. The actions, as shown, are typical of mine sites and reflect a lack of long-term thinking when life-of-mine-thinking is of the utmost importance to shareholders.

The MMG (1997) economic modelling approach used in this study, advocates a focus on all the key components of value creation in the business to provide a comprehensive decision framework. The basic framework contains the following characteristics:
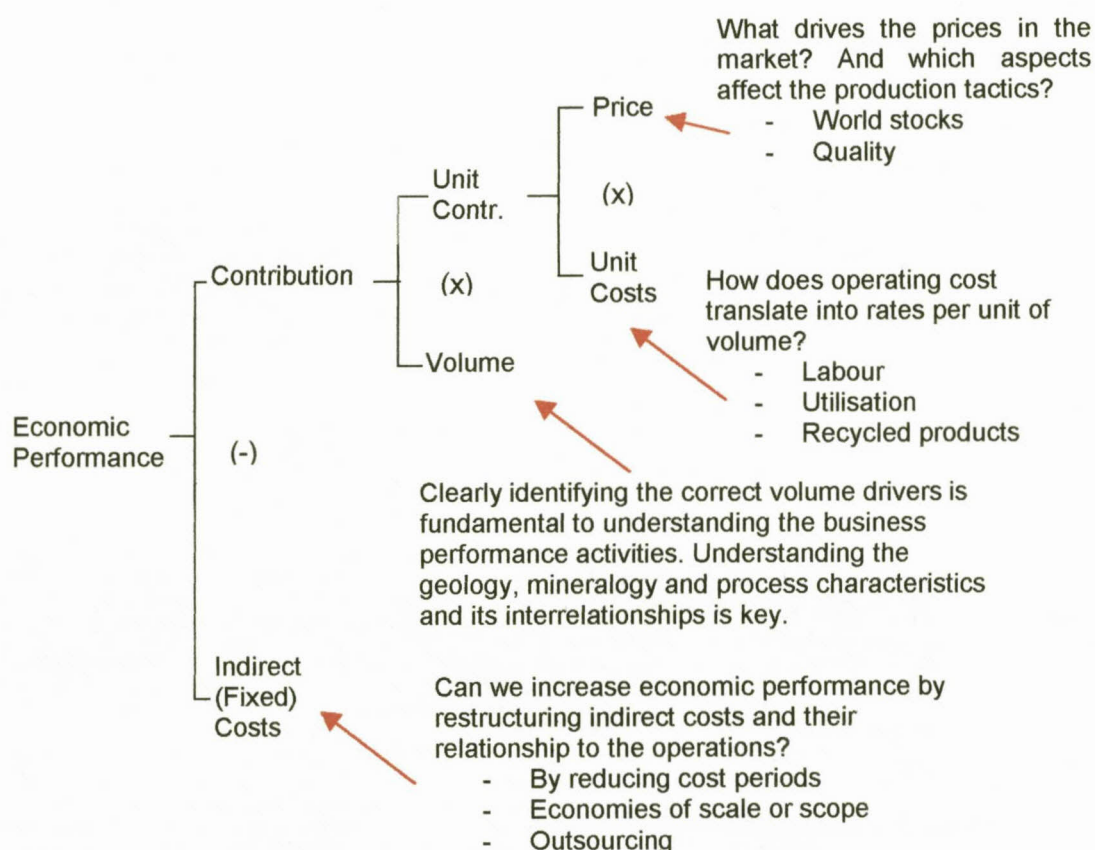


**Figure 3.4b. The contribution approach to modelling profit drivers (Mitchell Madison Group, 1997)**

One might mistake this form of the structure as similar to the traditional approach if one does not realise that the breakdown should be perpetuated down the respective

branches. The results of the study at hand discussed in section 5 illustrate the depth and power of the modelling approach. The typical decision leading to actions (with the consequences listed above) taken under the traditional approach is put into perspective by offsetting consequential costs against the benefits with the alternative approach applied here.

Applying the contribution approach therefore helps in establishing a rigorous framework and set of tools for the business that:

- Describes the economic **imperatives** of the business

- Highlights the management **trade-offs**

- And allows "what-if" issue and scenario **analysis**

It leaves the business with an economic framework that supports the above without the constant need for external consultants. It further serves as a catalyst to start the creative process of performance management, assisting management teams to focus on the issues that matter.

## 3.5 Commodity pricing impacts

During the project it became evident that an important economic factor, namely metal pricing behaviour, which offered an extensive profit opportunity, has not been adequately understood. Nor has the opportunities been considered in tactical and medium-term planning.

The theory of options and hedging has been widely described (Ross, Westerfield and Jaffe,1990:561-593; Brealy and Myers, 1988:607-627). In all these texts, the fluid relationship between metal prices and time, which lies at the heart of every hedging transaction, is treated in a very "mathematical" way as opposed to what risks it really holds for the business. One needs to approach the manuals used by practitioners like the London Metals Exchange (LME) (Base Metals Handbook,

1993) before one considers the true impact on metal price determination. The mere essence of the theory is reflected here and adapted for purposes of the study.

At the heart of the metal pricing mechanism lie three things, namely:

- World metal **inventories** which result from the recent metal supply and demand imbalances,
- Metal prices as "discovered" (i.e. not "determined" as if in a prescribed way) by the metal exchanges like the Commodities Exchange Inc (COMEX), or the London Metals Exchange (LME) based on the status of the Supply-Demand balance,
- Current spot prices and the future prices at various agreed points in the future resulting from the current trade in future sales and purchases.

Now, two specific situations of interest to a metal producer exist, namely a *contango* or *backwardation*. In a totally logical world, it would follow that the price pattern for any metal would be a straight-line increase from the current time to any forward date, starting from the current spot price to the current price for an agreed sale in the future.

The angle of the line would be dictated by three factors: the *cost of finance*, which is the largest of the three, the *cost of insurance* and the *cost of storage*. The cost of finance is usually expressed as the risk-free rate, as depicted in figure 3.5 below, excluding the other two nominal costs for simplicity's sake.

If, therefore, the current metal price is $1200/t and the risk-free rate is 10%p.a., one should expect to pay $1320/t in 12 months' time. Assuming that the future price ($1320/t) is indeed more than the current price, the difference between the prices at those two dates is called a contango. This is the equilibrium price situation assuming the supply-demand situation is in balance and at the current average cost of capital.
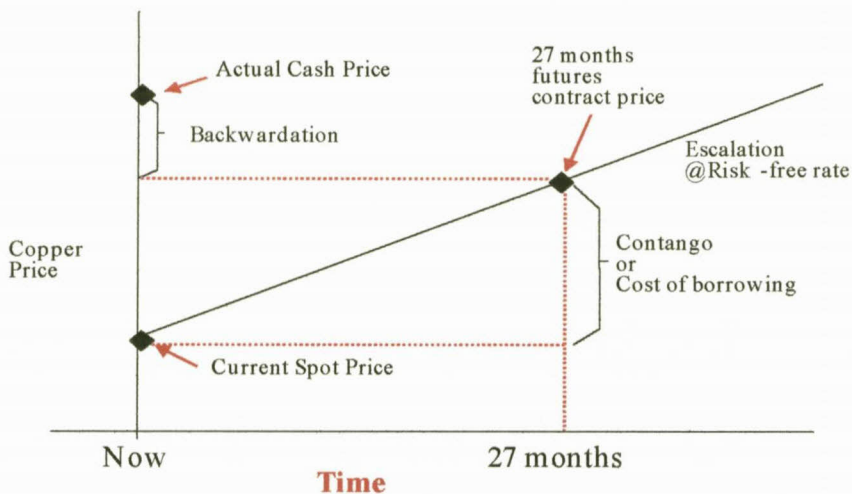
**Figure 3.5 Metal Pricing Conditions: Backwardation versus Contango**

Although this sounds surreal, market mechanisms tend to show that the contango is usually limited by the cost of finance (which is the greater of the three risk-free rate determinants). The reason is that should, at any time, the forward price be higher than the cost of finance, investors will move their money out of bank accounts into metal purchases. The result of this situation is that whenever the contango in a contract rises above the cost of finance, there is a rush of metal buyers who want to sell the metal forward at a profit. The laws of supply and demand prevail and the nearby prices rise in response to the buying pressure, while the forward price falls under the selling pressure and the difference between the two prices (the contango) falls back into line with the cost of finance. A contango is the logical state in which a market should find itself, provided supply and demand are in approximate balance.

An important corollary to the rising metal price is that the cost of production rises at that same risk-free rate. Theoretically, the margins that producers earn should remain constant as the unit price and cost rise in concert. The only way for a producer to increase margins is therefore to reduce the cost of production. Moving production forward is merely reaping the next year's profit this year. *Provided, as it will be illustrated later in this text, that production is moved forward under specific circumstances like backwardation, which temporarily swing the balance in favour of current sales.*

However, markets are rarely so obliging - as a matter of fact, the reason why markets exist is because of their unpredictable nature, which, of course, creates the opportunity to make money – or lose it. As the diagram illustrates, it does happen that the current price shoots up to a level higher than the futures price, causing the opposite situation of the contango, called *backwardation*. Say, for example, one has a 12-month futures price of $1200/t and the current price sits at $1300/t. The $100/t discount on metal delivered in twelve months' time is called *backwardation*.

This situation can occur when, for example, a shortage of metal develops due to a strong, sudden demand for metal and/or suppliers collectively fail to deliver as predicted. Buyers will pay a premium to keep their plants running, or deliver on promises now by taking up all metal available. This happened during the 1950s after the Second World War when there was not enough copper supply for rebuilding the infrastructure lost during the war, which led to a huge backlog in the supply of copper metal. It again happened during the period of the study for reasons still not perfectly clear. Reasons cited were poor world LME inventory reporting systems, Russian and Chinese production not delivering according to forecasts and the like.

One could conceivably exploit the futures markets through hedging and situations like backwardation for the metal producers including mines. As will be discussed in the results section, if the production of metal from ore takes, say, two to three months, and there is upstream inventory, an opportunity to sell intermediate products at a higher price than the final product might arise. These concepts are certainly thought-provoking, especially in the case of mining companies that have survived numerous economic challenges by conservative spending and decision-making.

## 3.6 Economic Value-add - EVA®

The EVA® concept is a topic that has been widely published and debated during the last decade (Stewart, 1991). The relevance of this concept to the study reported on here is that the modelling approach taken, enabled one to take an EVA® -view by

simply extracting the relevant information from the Focus® model. The view it shed on the performance of the company was a shocking one and hence, provided a real stimulus for change.

The aim of this section is not to explain the EVA® principles in detail but rather to indicate how they support the objectives of the study at hand. Stewart and Stern (1990) in *Quest for Value – The EVA® management guide*, believes that three imperatives will establish the foundation of economic wealth in organisations, namely:

- **Planning for economic value** – to plan and act to maximise the wealth of the organisation over its complete life cycle and not just for the financial year.

- **Changing managers into owners** – link wealth creation to the reward scheme in a way that rewards people to think in accordance with the planning horizon they are responsible for in order to maximise wealth, not merely to secure short-term profits.

- **Restructuring of finances** – Changing the financial system to embed the principles of EVA® in planning, executing and reporting. In Theory of Constraints terms, this is about removing "policy constraints", i.e. not physical constraints but the rules created by management that prevent the organisation from performing better.

Economic Value-add or EVA® *is the operating profit less the cost of all the capital employed to produce those earnings.* The concept drives this novel, yet different way of building the economic wealth of an organisation (Stewart and Stern, 1990:2). It is based on investigations into what it is that determines the drivers of market value or wealth of an organisation. It lead to the understanding that:

*Market values are determined not by the cash that has gone into the acquisition of the assets, but by the cash flow that can subsequently be gotten out of the assets (over the life of mine for instance). It is therefore a management imperative to add value to the current market value of the organisation through the application of sound (EVA®) principles (Stewart and Stern, 1990).*

The key aspect here is the departure from short-term profit thinking towards a longer-term wealth-creation mode of thinking and acting. These principles have been the same as those used during the profit-modelling project described in this report. It manifests itself in the Focus® models in correcting the short-term profits into long-term adding of wealth; profits that were achieved this year by moving forward production have less of a positive wealth impact than generally accepted. In Stewart's (1990: 56) terms: "the pressures for short-term results put unnecessary hurdles in the way of sound management".

This short paragraph cannot do justice to the wider ambit addressed by the EVA®-principles. These principles hit much wider as they insist on not only changing the financial system but also setting the rules for optimal performance rewarding scheme. Further investigation into absorbing this thinking into the management of minerals resources will be necessary to align the accounting system with this modern thinking.

## 3.7 FOCUS®

The FOCUS® Toolkit is a modelling system built on spreadsheet technology, using the Mitchell Madison Group's approach to economic modelling. It has been used extensively by the Thomas and Sylvester consultancy across the world in various industries covering natural resources, utilities, banking and even manufacturing concerns.

The modelling takes place in Microsoft Excel® or MS SQL® as database using an application layer developed in $C^{++}$. The tool provides a variety of ways to view the model, as well as analyse for sources of variance and sources of change. The *Source Of Variance (SOV)* measures the percentage impact of the variance against the budget of the node of one's choice. The *Source Of Change (SOC)* measures the impact of change between Year-to-Date Actuals 12 months apart, essentially a year-on-year change assessment.

An overview of some of the features of this tool will illustrate its power for projects of this nature:

a. The Profit Control® view provides a nested view of the model with some selected columns of data (Fig. 3.6a). This allows one to "explode" or "collapse" the areas of interest in the model for investigation or reporting:

| | | Monthly May 1995 | | | |
| --- | --- | --- | --- | --- | --- |
| | | Actual | Budget | Variance | Last Mth |
| Long-Run Profit | kR | 60057 | 101365 | -41309 | 57221 |
| Short-Run Profit (EBIT) | kR | 57481 | 102694 | -45213 | 66787 |
| Marketing Value Added | kR | 3353 | 337 | 3016 | 4394 |
| Value Added - Rod | kR | 62 | 337 | -275 | 868 |
| Value Added - Cathode | kR | 3291 | 0 | 3291 | 3526 |
| Value Added - Concentrate | kR | 0 | 0 | 0 | 0 |
| Site Value Added | kR | 80684 | 16824 | 63860 | 85105 |
| Smelter & Refinery Value Added | kR | 5079 | 21077 | -15998 | 6453 |
| Mining and Milling Value Added | kR | 87304 | -944 | 88248 | 90648 |
| Sundry Costs | kR | 5856 | 3310 | 2546 | 5500 |
| Indirect Costs - Site | kR | 5844 | 0 | 5844 | 6497 |
| Indirect Costs - non Operating | kR | 2838 | 2838 | 0 | 2726 |
| Accounting Adjustments | kR | 23719 | -88371 | 112089 | 19986 |
| Long - Short run Profit effect | kR | 2576 | -1328 | 3904 | -9565 |
| Management Information | | 0.00 | 0.00 | 0.00 | 0.00 |

**Figure 3.6a. The Profit Control® View (Palabora Focus Model, 1995)**

The few open-nested structures are illustrated above with units and configurable columns on the right.

b. A different view of these, referred to as Profit Drivers®, with an even more marked focus, in a different reporting format, is illustrated in figure 3.6b. The relationships are, however, very clear and "drilling down" a branch of interest is intuitive.

Both these reporting formats have, however, one drawback in that they represent a snapshot of the situation at a given period of time.

**Palabora**

Monthly Actuals
May 1995

| | Marketing Value Added kR | |
|---|---|---|
| 3353 | 337 | 3016 |

| | Site Value Added kR | |
|---|---|---|
| 80684 | 16824 | 63860 |

| Short-Run Profit (EBIT) kR | | |
|---|---|---|
| 57481 | 102694 | -45213 |

| | Indirect Costs - non Operating kR | |
|---|---|---|
| 2838 | 2838 | 0 |

| | Accounting Adjustments kR | |
|---|---|---|
| 23719 | -88371 | 112089 |

| | Mill Volume Effect kR | |
|---|---|---|
| 2576 | -93 | 2668 |

| Long - Short run Profit effect kR | | |
|---|---|---|
| 2576 | -1328 | 3904 |

| | Smelter Volume Effect Rm | |
|---|---|---|
| 0 | -1236 | 1236 |

| Long-Run Profit kR | | |
|---|---|---|
| 60057 | 101365 | -41309 |

| Actual | Budget | Variance |

| | Ore Stockpile Analysis kR | |
|---|---|---|
| 141 | -965 | 1105 |

| | Stock Information | |
|---|---|---|
| 0.00 | 0.00 | 0.00 |

| | Mill Performance /t ore | |
|---|---|---|
| 0.00 | 0.00 | 0.00 |

| Management Information | | |
|---|---|---|
| 0.00 | 0.00 | 0.00 |

| | Net Profit derived from Model R | |
|---|---|---|
| 60985973 | 102693652 | -41707679 |

| | Net Profit per Income Statement R | |
|---|---|---|
| 60985973 | 102693652 | -41707679 |

| | Data Entry | |
|---|---|---|
| 0.00 | 0.00 | 0.00 |

**Figure 3.6b. The Profit Drivers® View (Palabora Focus Model, 1995)**

c. Two views are possible within the tool, namely, one with a more pronounced focus on the trends and the other with a more pronounced focus on the relationships without losing sight of the trends in figure 3.6c. The first is called Profit Trends®:
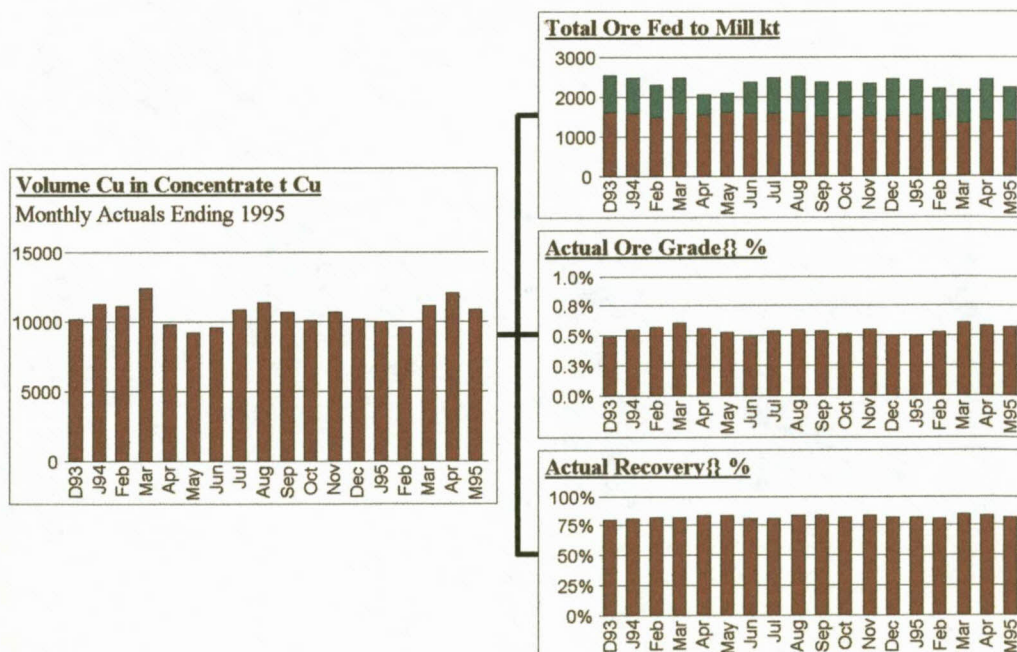


**Figure 3.6c. The Profit Trend® View (Palabora Focus Model, 1995)**

Again one can move up or down the complete relationship structure and see whether one trend is explained by the trends of its underlying drivers. Here one can see how the trend in copper volume reporting to concentrate is described by the trends of the ore feed to the milling section, the ore grade and the recovery.

d. Profit Charts® view in figure 3.6d provides for a powerful view where only certain sub-trees might be required to be visible. This is particularly useful in a discussion around the interrelationships amongst a certain set of drivers within the context of the other drivers or branches. This view allows one to collapse unwanted branches and explode those of specific interest to the discussion.

e. Following on from the normal reporting views, and as described in the results in Section 5, determining the key profit drivers is the main focus of the project. FOCUS® provides variance analysis functions, which will determine the variance of all lower level drivers on a chosen higher-level outcome or driver.
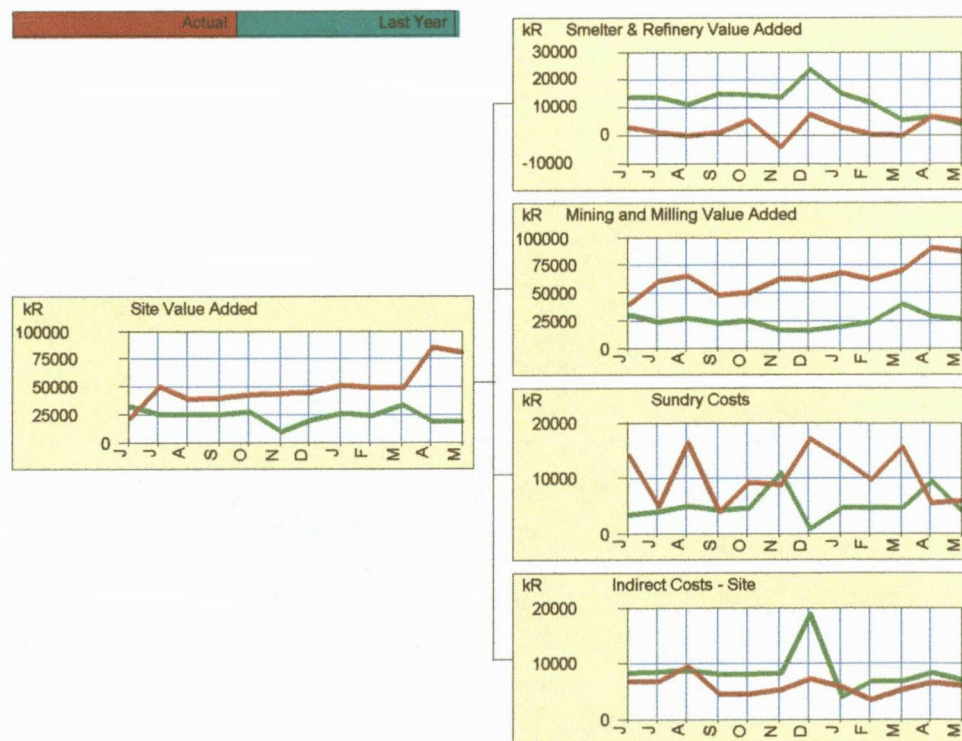


**Figure 3.6d. The Profit Charts® View (Palabora Focus Model, 1995)**

One may rank all the drivers by the size of the variance caused on the outcome, e.g. the corporate bottom line gives one an idea of which individual driver causes the most variance. As shown in the results section, this sets one up for determining the key profit drivers.

One way of representing the top or key profit drivers of an organisation is to determine the possible improvement value that can be extracted for each of the key drivers. Profit Waterfalls® represents this as follows:
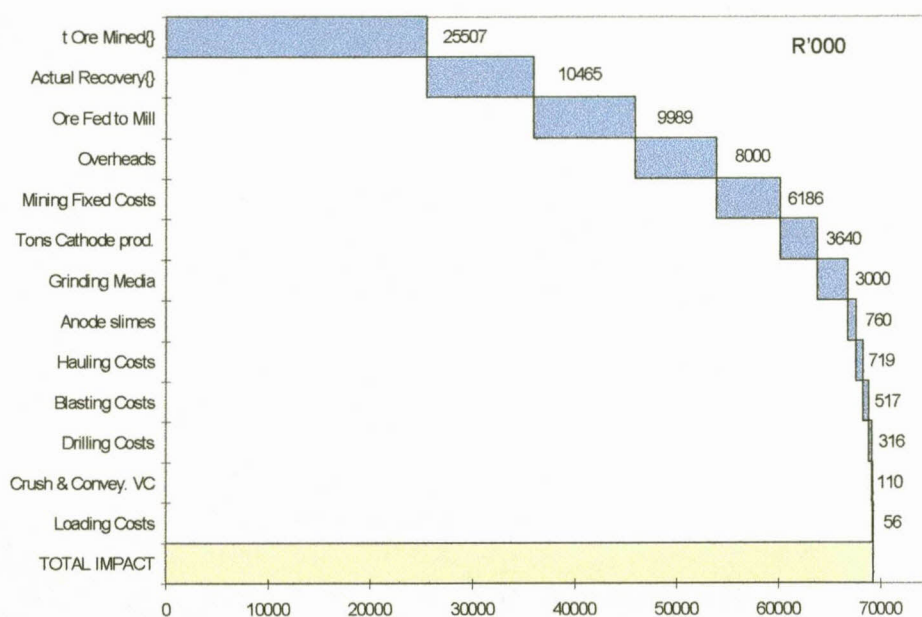


**Figure 3.6e. The Profit Control® View (Palabora Focus Model, 1995)**

Here, one can see how the tons of ore mined can offer the highest reward if close attention is paid to this driver, followed by recovery performance, ore milled, etc.

The FOCUS® tool is central to the solution kit used in the study. The project approach, described in Section 4, hinges on the modelling tool as it offers the following support to the team:

- It allowed the study team to capture a rough understanding into a structure as input to discussions, using the principles that distinguish it from any other approach.

- The integration of the loose-standing sub-models takes place in the system; its ability to allow the team to traverse the integrated structures makes for a better understanding of the macro-business model.

- The database of the system, together with the structures, makes for a powerful data warehouse where islands of data can be collated in business context.

- The powerful reporting views lend remarkeable credibility to the structures since the trends confirm and clarify the interrelationships.

- The SOC and SOV functions described above, together with the Profit Waterfalls®, extend the use of the model towards the management of continuous improvement initiatives in the organisation.

- Taking alternative views of the business to assess concepts like EVA® is relatively quick and simple due to the data integrity within structured database and relationships.

Without this tool, a project of this nature can become cumbersome and is bound to lose impact. This is due to the time it will take to structure data into useful information, and the absence of a unique presentation of the information to management teams.

# 4 Business Modelling Project

## 4.1 Goals and Objectives

This study aims to demonstrate how the approach described in this section provides the context, concepts and tools for an organisation to extract the key business issues, develop and test alternative solutions in a way that aligns the organisations resources.

As a result, business modelling is transformed into an interactive, value-adding medium for the planning and execution of business plans by cross-functional management teams. It allows management teams to reduce the strategic planning cycle times and to translate strategy into action by linking strategic information to tactical information.

The project was initiated due to the need for revisiting Palabora Mining Company's views of what makes organisations perform and to find ways of improving mining organisations' performance. The project objectives were as follows:

(i) Fundamentally to **review the understanding** of **what drives the economic performance** of the organisation. Also to highlight all key business issues within the organisation.

(ii) To identify Key Profit Drivers (KPD's) for the complete value chain and then quantify and structure the relationships into an hierarchical KPD model. Also to **provide alternative solutions for the key business issues** listed in the previous step using the KPD Model.

(iii) The ultimate objective is to **establish the framework for continuous improvement.** To establish ownership within the organisation for the profit driver model for strategic planning, performance assessment and team-based planning and execution.

## 4.2 The Project Approach

Figure 4.2a illustrates the main phases of the project. The go-ahead decision points are to offset cost vs. estimated incremental value derived from the project. At the first point the sponsor might not be convinced that the returns might be sufficient to cover expenses, and might want to terminate the project. In actual fact, it also serves as a comforting purpose for management teams that are not convinced that their business would substantially benefit from this project approach. They then know before the project starts that there is a point where the project can be terminated, should there be no value to be foreseen. The second point is for the management team to decide whether they want the model to be included in their planning and performance assessment business processes or to accept the modelling process as a once-off exercise.
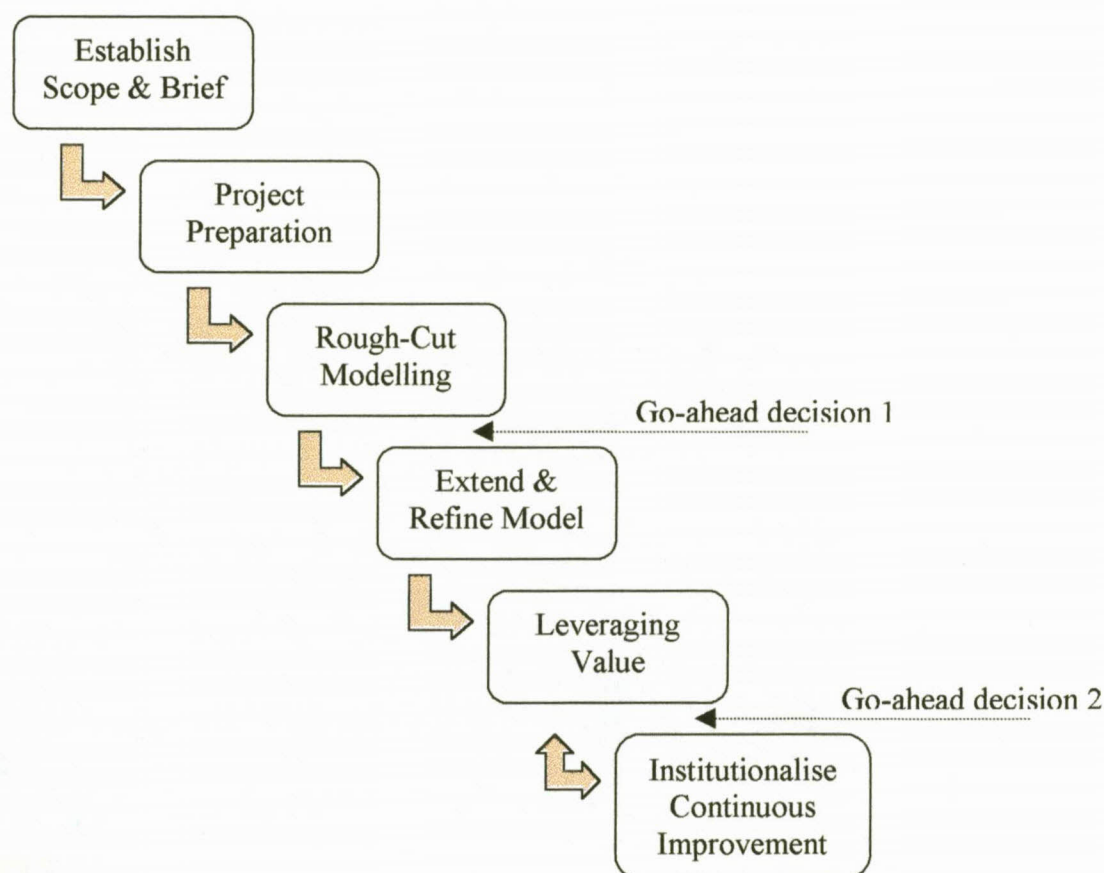


Figure 4.2a. High-level summary of project steps (Sylvester and van Niekerk, 1995)

A further level of breakdown of these project steps, to show the outputs of each step, is presented in table 4.2a. No two projects are the same and neither are all projects successful. The table is based on the particular project and the steps that were deemed necessary. Depending on the brief, scope and situation in the company these steps might look differently.

Too many variables impact on projects to allow for certain basic elements not to be in place. One of these basic elements is the actual project scope and objectives. The nature of the project, which is subject to this study, and started of with broad and vague requirements required constant contact with the project sponsor.

The rest of this section elaborates on each of the phases in table 4.2a.

## 4.2.1 Establish a clear project scope and brief

The process of establishing a clear brief involves:

- Initial discussions with the project sponsor

- Documenting the brief and scope as draft discussion document

- Clarifying and reaching agreement with the sponsor, where possible

- Discussing it with key players within the organisation

- And lastly, drafting a project plan and budget which needs to be signed off

The project was divided into stages to ensure that the management team signed off on a rough-cut assessment and model before moving on. This staged approach ensures that the teams are up to date with the developments and that funds spent are related to stage deliverables.

**Table 4.2a. Outputs from project steps (Palabora Focus Model, 1995)**

| Business Modelling Project | | |
|---|---|---|
| Phase | Step | Outputs |
| Phase 1 - Project Preparation | | |
| | Clarify Scope and Brief | Clear scope and brief |
| | Set up project infrastructure | |
| | Train project team | Functional team |
| Phase 2 - Build Rough-cut Model | | |
| | High level core process chain | |
| | | Core process chain |
| | | Bottlenecks |
| | | Improvement Opportunities |
| | Business context definition | |
| | | Understanding the business nature |
| | | Assess the products and market situation |
| | | Assess what constitutes value to shareholders |
| | List business issues | |
| | | Business issue maps |
| | | Understanding of causal factors |
| | | Business involvement |
| | Develop rough-cut model | |
| | | Model structure logic |
| | | Rough-cut model |
| | | Updated sponsor and management team |
| | | Broad arguments around opportunities/issues |
| | Give fedback to sponsors | Go-ahead |
| Phase 3 - Refine and extend model | | |
| | Refine model | |
| | First data take-on | |
| | | Detailed but limited model |
| | Extend for planning periods | |
| | Further data take-on | |
| | | Extended model ready for SOC & SOV |
| | | Complete performance drivers list |
| Phase 4 - Leverage for business value | | |
| | Variance analysis | |
| | | Key profit drivers selected |
| | | Ranked focal areas for improvement |
| | Issue Based modelling | |
| | | Issue analysis with alternative solutions |
| | | Substantiated arguments & justifications |
| | Business engagement | |
| | | Further agreement and alignment |
| Phase 5 - Enabling continuous improvement | | |
| | Identify sponsors | Accountable sponsor |
| | Identify model owner | Accountable owner for maintenance |
| | Panning Process Design | |
| | | Clear business planning model |
| | Clarify required Information Architecture | |
| | | Information architecture Designs |
| | | Data collection templates = warehouse design |
| | Clarify organisational changes | |
| | | Process team designs |

## 4.2.2 Project preparation

During project preparation the team members are identified, roles and responsibilities are defined. The project environment is set up to allow for team sessions, and with access to networks for access to business data for modelling. The phases of the project are delineated and an action plan drafted.

(i)     With the initial project plan in place, the process of continual updating of the management team is initiated. The objectives and phases of the project, as well as the resource requirements from the organisation, are explained to the management team. This takes the form of a management contract to ensure commitment for the phases to follow. Management expectations are carefully managed throughout the project.

(ii)    The training of the team in the specific modelling principles and techniques follows. Essential economic principles (as described in section 3) that apply to the resource industry, are revisited to bring the team up to speed. Some of the key aspects are discussed in the next section as these form the basis of constructing sound arguments when alternative solutions are defined.

This phase allows the team to settle down into the team roles, establish commitment to a daily time schedule and become conversant with the modelling techniques.

## 4.2.3 Rough-cut modelling of Business

This phase involves, firstly, the identification of the external factors and business theories that impact on the profitability or perception of business success. The share price, trends and various ratios like the Price:Earnings (P:E) ratio that reflects the valuation of mining companies by shareholders is a typical example. Understanding how shareholders perceive value will determine how the top layers of the business model will be structured. The fluctuations in commodity prices is one of the larger risk factors in the industry, and is another example of external factors that must be

considered in the business modelling process.

Secondly, the business issues internal to the organisation need to be assessed and understood. The involvement of the decision-makers at various levels of the organisation is essential to build and facilitate an understanding of these issues and which factors are perceived to be causing them.

The outcomes of this phase must include:

- An understanding of what **core** and **non-core** business processes are. The core process steps need to be defined and the **performance measures** that are used by the organisation.

- A broad understanding of the **factors and issues** affecting business performance

- A rough-cut business model that reflects the understanding of the above in order to play back the **implications** thereof and **possible conflicting beliefs** to the organisation

- A **general acceptance** of the engagement process by the key players within the business

- Some **convergence** on the issues within the business teams through focused, facilitated debate.

### 4.2.3.1 Define the core processes in the value chain

The next step requires the team to narrow their focus down to the organisation itself and plot the high level steps in the process value chain. The objectives are:

- To create a clear view core process chain with specific references to the processes, the transportation network and buffers or stockpiles used

- Within the process chain, point out the constraints or bottlenecks

- To solicit business issues and opportunities

- To gain an understanding and to document the measurements used in managing the business

The focus will be on the core processes only as described in the section on Supply Chain Management. Support processes are a function of core process requirements and may be addressed in a subsequent project. As such, the costs of support processes and the impact they might have on any bottleneck in the organisation are the only issues considered in this study.

Again, a layered approach to the modelling process is taken to ensure that discussions are focused.

Additional layers of process details are added to the diagrams with every pass. By-products are tackled after the core processes have been discussed to its lowest levels. To maintain the high level of discussion at first, the three building blocks to be used at first are *Processing, Transportation, and Stockpiling*. These three building blocks are sufficient to establish the core process flows. The ideal is to make these diagrams visible in the project room, as well as stimulate debate on relationships between variables and business issues. The process drawings will be used as an input to the subsequent phases to maintain process-centered thinking.

Bottlenecks, challenges and opportunities should be indicated on the diagrams during discussions and documented as input to the later stages.

- Areas of concern in the core processes should be revisited in the next pass to add more detail description to the business issues, which are carefully documented. With this pass, the measurements and norms used in managing the processes are also documented. When documenting these measurements, it is important to indicate what the measurements are used for and what aspects of the business are controlled through these measurements.

- The by-products and ancillary processes, which are integrated parts of the core production processes are subsequently analysed in the same way as

the above. The impact on the core processes should also be indicated clearly.

The outcomes of this step are:

- The core process steps and the ancillary by-product core steps

- A set of measurements and norms per core process

- An understanding of what causes the variation in the measurements and control objectives within the processes listed above

### 4.2.3.2 Business context definition

An environmental scan requires the team to revisit the field of business involved. The nature of the business determines how the company is valued and how it could attract optimal value for its shareholders. All the stated accepted practices are questioned as to their validity and might require the team to be divided up to play the roles of information providers and devil's advocates. A typical series of questions would be the following:

- What is the business we are in? How does it differ from other industries and what are the implications of these differences?

- How has the business been conducted traditionally? Are there any obvious flaws in doing business this way?

- How do we plan and optimise our business operations? Are there better ways of doing this in the light of modern developments?

- Where are our markets and what is driving them? How does this impact on our business? Are there any discernible trends in the market that might indicate changes to our business?

- How is the ore reserve viewed? Is this the optimal view? Should the respective organisations having rights to the same reserve be collating their interests or not?

- How is cut-off ore-grade determined?

- Where is the throughput bottleneck in the production chain?

- What is the basis on which the optimal production throughput is determined?

- On what basis are decisions regarding the smelting or selling of concentrate stocks decided on?

- Are the ore reserves finite or not? Is the appropriate view taken as a consequence of the abundance of the resource?

- If relevant, how are external economic indicators applied to the business?

- Are accountabilities and responsibilities clearly defined?

- Are the right drivers for the business identified? On what basis?

The outcome of this step is an affirmation of the business nature, and a verification of the ways business is conducted. It should highlight areas of opportunity in approaching the business differently. The highlighted areas will be investigated with a comprehensive model in place.

The further objective of this step is to prompt the team to start questioning assumptions and think outside their normal domains. It aims to establish broad assumptions about the business that need to be verified later in the project when the information and mechanisms are in place to do so.

### 4.2.3.3 List key business issues influencing the performance of the organisation

The team would first list "areas of pain" as these are generally known within organisations. These items are verified with business managers and specialists through a series of interviews. Like the areas of opportunity mentioned above, these "hot spots" will later be studied, using a business model. It serves as an assessment of the nature of the problems in the organisation.

The objective with this step is to refine the draft issues from the previous step and discuss these widely in the organisation to solicit a broader input and foster debate among and within process teams regarding the issues and their possible causes.

The lists of issues will affect the emphasis during the modelling process in order to maximize the business returns from the project. Arguments that may be used to elucidate the issues will be constructed to facilitate further debate and precipitate a better understanding of the issue and the making of decisions that will address the issues.

### 4.2.3.4 Evaluate the (causal) factors involved with the listed issues

The process is now taken a step further by debating what the causes are of the areas of pain. Causal factors are listed to establish a better understanding of the hidden rules that govern planning and execution within the organisation. These factors will be tested in the subsequent modelling process.

This step again further refines output from the previous step by investigating the causal factors, as well as how these factors relate to each other. The nature and magnitude of these relationships are revisited and supporting data requested from the operations and research departments.

### 4.2.3.5 Discuss factors and issues with relevant parties

Further refine the initial discussions with operations management and specialists, now generating an understanding of the real drivers of the business. This round of discussions aims to stimulate thinking within planning and execution teams. All "rules" are challenged and left to the teams to resolve. This form of engagement avoids the situation where the modelling team is perceived as planning in ways that are removed from the reality of the day-to-day business.

With the output from the previous step, and more data to substantiate the relationships between variables spanning across the value chain, the respective teams are drawn into focused discussion to enhance an understanding of the situation.

The lists of issues are modified as interrelationships become clear and the importance of the one issue in relation to the next is established.

The outcomes of the last few steps are:

- A refined set of critical business issues

- A linked set of factors that are perceived to cause the issues

- An indication of which of the issues should be resolved through other means than the modelling of the drivers

- An informed number of business teams engaging in the resolution of the issues at hand

### 4.2.3.6 Develop rough-cut model

The real modelling can now start to take place since the business context is defined and a rough understanding of the business has been developed. For the purposes of the ensuing discussions, the specific modelling concepts used in this project require further explanation.

### (i) Setting the model context

The contextual setting of the business model will be determined by the particular circumstances of the industry in which the business operates, as well as the aims of the business executives. The Mitchell Madison Group (1997) used four distinct classes of models, two of which are relevant to the mining industry:

| Model Class | Application | Problem characteristics |
|---|---|---|
| Mix of multiple products with scarce resource | ✓ Timber, oil and quarries | Shared resources causes trade-off between different elements of the mix, e.g. producing various grades of vermiculite |
| Opportunity cost | ✓ Mining de-bottlenecking<br><br>✓ Process throughput vs. yield<br><br>✓ Maintenance bottlenecks | A. Accounting system does not reflect economic trade-offs/costs<br>Or<br>B. Opportunity cost models can represent the key strategic issue in the business or simply an isolated problem |

The contextual setting is the structure of the highest levels of the model into which all the lower branches "plug in". Refer to the profit driver tree structure diagrams of the following examples:

- Should a business want a more generic view of the business, an income statement and/or a balance sheet can be used as highest level of summary in the model. In this study the complete business had been structured in such a way that this aspect was reflected in the income sheet items. Note, however, that the accounting method that has been chosen for the modelling process, might be of particular importance to the business as it might reflect the business in a fresh, yet acceptable way. For more clarity, refer to section 3 where the differences between two traditional accounting approaches are highlighted.

- Another way of structuring the model may be by using the various divisions or branches of the business. In this instance an economic view of operations is taken, especially when trade-offs between the various branches are to be considered during the optimization of the business. This study, for instance, had to consider, during periods when metal prices were in backwardation, a trade-off between selling concentrates immediately or producing final metals products for selling later. This economic condition is also described in section 3.

- A third approach is usually aimed at augmenting the business model with alternative scenarios. Whilst the business model aims to take a strategic view of the business as a whole, certain specific critical business issues are addressed individually. These branches of the model use the data from the model and demonstrate the trade-offs that the business has to make in resolving the specific issue.
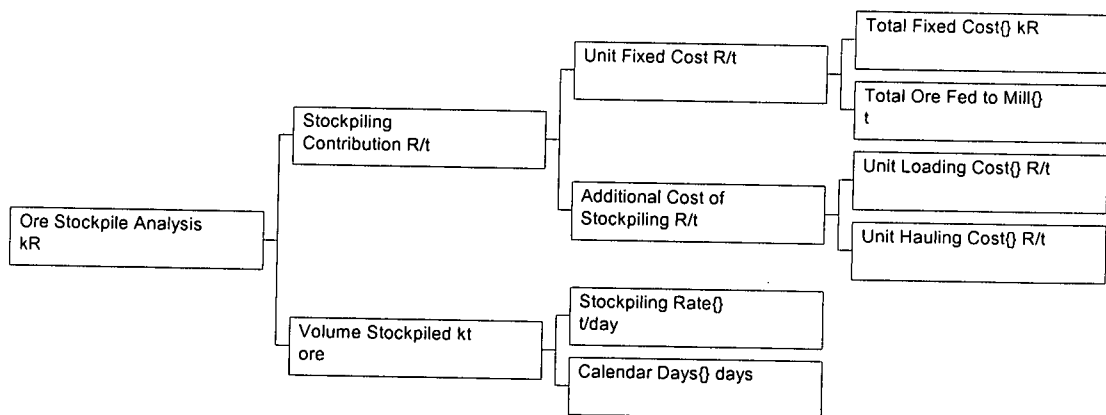


**Figure 4.2b. Issue Map for Ore Stockpile Analysis (Palabora Focus Model, 1995)**

## (ii) The principles of profit driver modelling

Before the actual principles can be discussed, the structure of a profit driver tree has to be understood. Refer to figure 4.2c below:
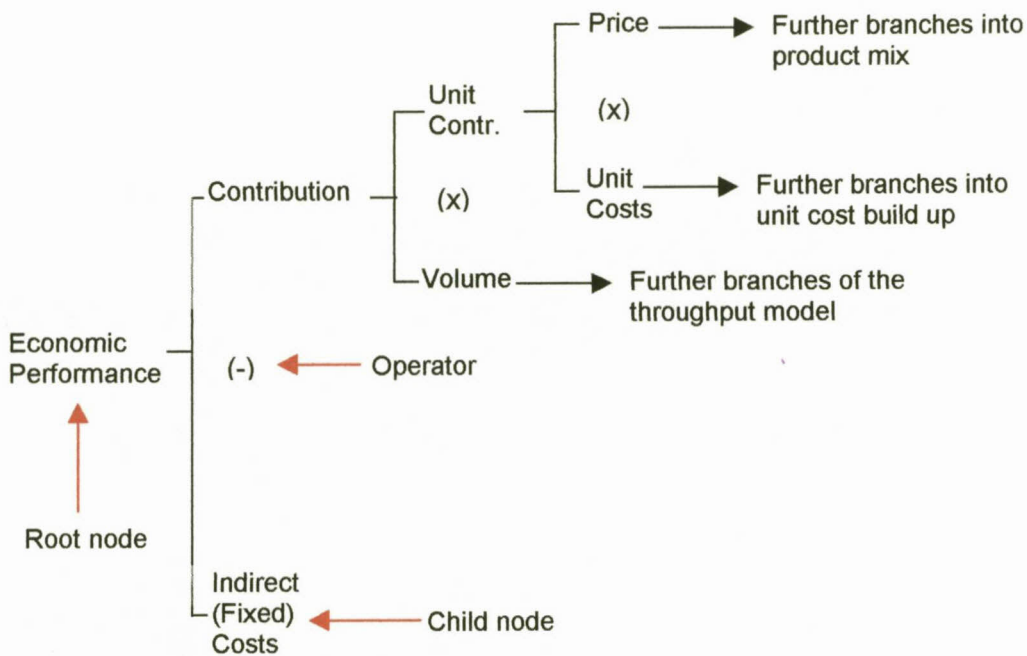
**Figure 4.2c. A basic economic Value-add structure (Sylvester, 1995)**

The structure consists of nodes and relationship links. Any node with two or more nodes connected to it is the *parent* (or consequential) node, which derives its value from the *children* nodes connected to it.

A few simple, yet fundamentally important, principles underpin the modelling approach. The most important principles are:

## Principle 1: Mutual exclusivity of child nodes (drivers)

- No two branches in a hierarchy may include part of each other's effects on the common or parent node. If this principle is not adhered to, the ranking of drivers becomes impossible since it is not clear which of the nodes' effects are responsible for a particular trend. There are two complementary techniques to ensure this rule is adhered to. The one technique is aimed at clarifying the macro-design and the other one lies in the mathematical design of the relationships. Both certainly require further elaboration:

### a) Macro-design – separating effects out:

Since most models in the resources industry investigate throughput and costs, a natural separation can be made by modelling throughput separately from variable unit costs as shown in the example above. These independent branches then join up as follows:

**Total cost = Unit cost per ton product x Volume output through value chain**
**(unit cost branch)          (volume branch)**

### b) Formula-design – accumulating and separating effects:

Important as it is to separate out the effects of variables affecting the same parent node, the same diligence has to be applied when modelling the additive effects down a process stream. Since each step in the core process chain affects the downstream process, each step's accumulated influences from prior processes are brought into the step. So, any downstream process performance is effectively calculated by a nested formula that reflects the joint effects of upstream processes, as follows (Sylvester, 1995):

**$Process_i$ output = Effective output from $Process_{(i-1)}$ x $efficiency_i$**

**$Process_i$ output = ($Process_{(i-1)}$ output x $efficiency_{(i-1)}$) x $efficiency_i$**

**Where:**

**$Process_{(i-1)}$ output = ($Process_{(i-2)}$ output x $efficiency_{(i-2)}$) x $efficiency_{(i-1)}$**

The structure is seldom if ever this simple and straight forward though but it makes for better illustration. At the lowest level of the throughput branch the formula will separate the drivers into final child nodes. For example, using a Peirce-Smith Converter (Biswas and Davenport, 1980) for copper fire-refining as an example:

**Say Throughput Rate (ton/day), same as $Process_1$ output in formulae above**

**= Throughput Rate (ton/hr) x Blowing Time (hr/day)**

**Where Blowing Time = Total hours per day (24 hr) x**

**Mechanical Availability (%) (Viz. ((24 – maintenance downtime(hr))/24)x100) x**

**Actual In Stack Time Ratio (%)**

**Principle 2: Completely exhaustive driver selection**

- The children nodes should describe the performance of the parent node completely. No significant numerical performance drivers should be left out. Disaggregated trees (trees where the children nodes are just a list of factors with no numerically defined relationship) could allow this to happen since there is no test for exhaustiveness. The following tree will probably not do:

**Predicted Mill Throughput (tpd) = Target Mill feed (tph) x Target milling time (hr/day)**

This structure assumes that only the actual milling time would affect the mill throughput. Provided the intention with the structure is to ignore the other important factors, it fails to indicate the effect of ore hardness, fine ore feed size, pulp density, etc. Without the inclusion of some of these, the structure would probably not add any insights anyway.

**Principle 3: Searching for the play-offs between alternative views**

The last but most important design principle is to structure the trees to offset effects against each other, especially in the issue trees. A simple example is to offset a unit cost branch against a unit pricing branch to arrive at the unit contribution, i.e. playing costs off against price to maximise contribution.

Taking the logic further - consider the issue: If increasing throughput generates more concentrate, knowing full well that metal recovery decreases at some with increasing throughput; at which point does the value lost through tailings exceed concentrate value gained? One should offset the increased revenue of an increase in throughput through a milling and beneficiation section against the simultaneous increased losses through reduced metal recovery.

This design principle allows one to do that without compromising on the rich structure behind the respective forces, i.e. it keeps track of the complete value chain and its performance factors. It is therefore not possible to venture outside the "validity zone" as is the case in applying relationships derived from multiple regression models.

For more advanced examples the long-term effect trees described in the results section will provide some food for thought.

The abovementioned principles do not negate nor allow the exclusion of a number of other important aspects of modelling like the use of reconcilable time units, data integrity, etc. which are issues that are not discussed in detail here. The computer system that was used with the modelling FOCUS® provided structured MS Excel® spreadsheets as the workbench for the modelling. The system provided the necessary disciplined structure to ensure that data integrity is maintained, time units are reconcilable and trouble-shooting is productive.

By applying the principles above, the performance drivers are structured and the interrelationships defined. The structure is then ready for data take-on from whichever source of information that is available.

## (iii) Data testing and take-on

A set of test data is drafted to verify the accuracy of the driver hierarchy. An ideal way is to provide the data for the low level factors first so that the higher structures are derived from basic principles. Comparing the outcomes with the actual information in operating and financial reports provides interesting insights into the reporting system of an organisation (or mistakes in the data model!).

Having tested the model logic, data take-on follows since the model structure clearly defines the required data sets. The sources of data-items are now identified and since data will be uploaded on a regular basis from these sources, ownership is established for all the sources of data. The owners of the source data have to be brought up to speed with their respective roles in the successful application of the model.

Before data are uploaded into the modelling system, the integrity of the data and data source has to be verified, especially if these come from satellite systems like spreadsheets or standalone programmes which, in turn, draw information from other systems. A rule-of-thumb is in order here: Always try and source data from the point closest to the original source.

An ideal is to create a data warehouse into which data are loaded from the various sources. A final check is done on these data to ensure integrity before the business model is updated through an upload programme or feature. Not all data have to be taken on at this point in time; the phase should mainly focus on the areas that relate to the issues of concern to the organisation.

**(iv) Initial trending and assessment of model value**

Using FOCUS®, it is now possible to display the relationships in various ways (see section 3 for the overview of the FOCUS® reporting views) with the aim of clarifying some of the business issues gathered in earlier steps of the project. With the main model in place, and due to the strong guiding principles mentioned above, issue maps can be developed. An issue map, as described in section 3, is a specific way of structuring the drivers underlying the issue and aids in clarifying it. The objective with the structure is to offset the various alternatives against each other so that the differential value (or cost) of the one is distinguishable from the other.

During rough-cut modelling only certain specific areas are developed to the point where the issue maps are sufficiently supported, i.e. to the point where arguments for or against an alternative in the issue maps can be supported.

Typical examples of the issues are:

- Given an excessive market metal pricing situation (in deep backwardation), should the concentrate stockpiles that is in excess of the safety buffers, be sold now or should it be processed in six month's time? Put it differently, at what point will the high income potential be better than the value-add through the rest of the production chain?

- Given the same market situation, and given that metal recovery reduces with increased mill throughput, how much more mill throughput can be maintained so that the excess concentrate produced will earn more revenue than the loss in metal through tailings?

Issue maps resemble the use of decision trees (Eppen *et al.*, 1988:638) without the application of probabilities as the objectives of the two approaches are the roughly same: "separating the assessments ... of the issues forces the manager to give appropriate and separate consideration to each alternative before comparing and choosing the best alternative...". And, according to the project's external performance consultant (personal interview with Neil Sylvester, 1996): "the aim is also to turn off complicating options to simplify the problem statement, provide clarity and to reduce the perception of risk which inhibits decision making".

The model then consists of:

- A rough-cut performance driver structure that starts off from an essential business view such as an income statement or value-add model. Assuming the income statement is used as context for the high level structure of the model, and then the elements of the income statement will expand into the driving factors of each. Typically one could expect fixed cost structures, a unit cost structure, and sales revenue structures. The latter will, of course, have to expand into the fully integrated core process structure of the production chain that will highlight bottlenecks with explicitly linked performance drivers. At the lowest level of detail, the rudimentary drivers of performance that are progressively accumulating their impact into higher level drivers in a mathematically sound way.

- A series of derived issue maps or tree structures to aid in the understanding of the operating teams of business issues of fundamental importance to the performance of the business

- The data for the more essential parts of the model are in the database. The planned data are also uploaded to show its accuracy and relevance or otherwise

**(v) Feedback to sponsors and teams**

The team now drafts an assessment of the issues at hand with an indication of the value extracted through the modelling process. At this juncture, it should be clear whether the process is adding value or not, and whether it promises more value if the project is to continue. Also to be considered at this point is whether only performance drivers (as oppose to the key performance drivers) are known. This will require the model to be extended to provide for cumulative, long term and medium forecasting capabilities, as well as variance analysis. Without this variance analysis, the real key performance drivers will be extremely difficult to determine.

## 4.2.4 Extend and refine model

If sufficient benefit was demonstrated in the feedback of the initial results, further development of the model commences.

### 4.2.4.1 Extending the model

The following additional aspects of the model are still to be developed:

- The lesser critical areas of the model are now extended to provider **a wider application of the business logic.** The full performance driver model is required for the variance analysis and key driver selection. Data for the complete model are sourced and added to the supporting data warehouse mentioned earlier.

- The data are also expanded for the **complete planning horizon.** A sensible model is to have daily information for the first three months, monthly for the rest of the year plus the next, and annual data for the next five years. Adding both planning and forecasted actual information provides for a sound planning sounding-board. Planning is usually done on more averaging and hence specific performance variances are not expected and hence, not planned for.

- The model can also be expanded to **collate the plans, actual and forecast performances** of the variables. This allows for trending of the year-on-year performances, and more comparative trend graphs.

- Further verification of the model's applicability through discussion with managers and teams is vital as the model grows in applicability for uses other than strategic and tactical planning. **Performance assessment** and **continuous improvement** are such powerful applications.

- It is at this point that the **data uploading is automated** to minimise the time required to update the model and minimise the cost of maintenance of the system.

### 4.2.4.2 Engaging the business issues

Through the process of reaching consensus on which variables drive which performances in the organisation, certain issues listed in the first phase will be resolved. The issues that are not resolved can then be addressed through additional issue maps.

The credibility of the model is vital in making this process a success. It is natural for some teams to resist the application of the model by introducing complicating factors that often stall progress. This resistance should be exploited to build the credibility of the model in resolving these complicating factors.

### 4.2.4.3 Determining key performance drivers

The collection of all the performance drivers in the performance model provides the basis for selecting the real key performance drivers that have to be focused on to maximize the bottom line impact. The usual response from business people on this remark is: "we know what the key drivers in our business are, what possibly can be expected from this process and model?" To understand why it is so important that a fundamental analysis of variables throughout the process chain is necessary, consider the following graph:
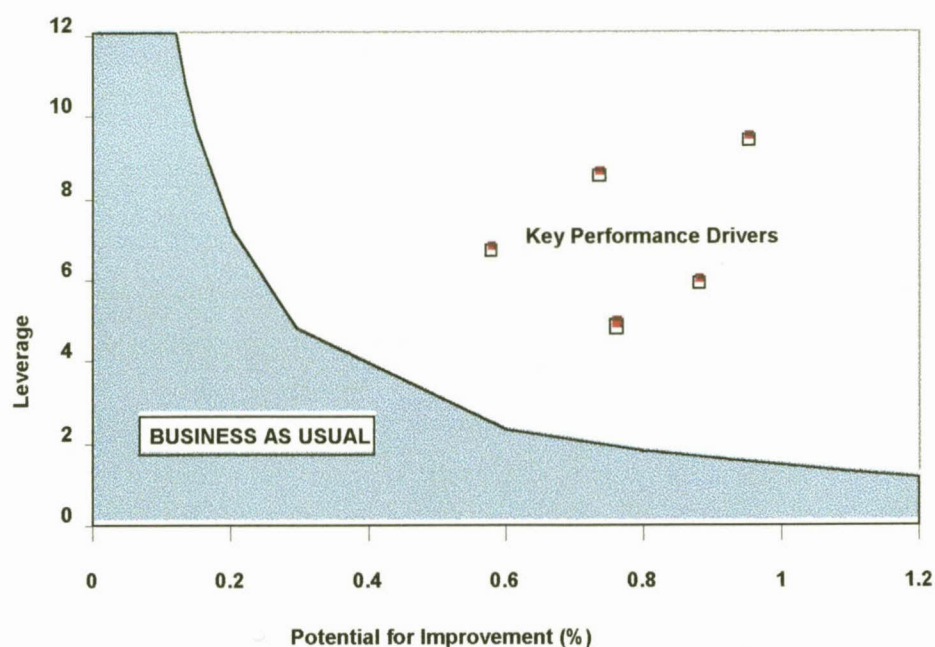
**Figure 4.2d. Leverage diagram for determining the key profit drivers (Palabora Focus Model, 1995)**

Consider a scale of increasing percentage potential for the improvement of any performance driver. On the y-axis, consider that, for any one percent change of a specific performance driver, the percentage impact on the corporate bottom-line profit increases. Should one plot the entire performance driver set in the model on these axes, a pattern will emerge where virtually all the drivers will fall within a hyperbolic boundary close to the two axes. This is the area one could call the "business as usual" zone. The reason for this phenomenon is that teams on-site will spot any high impact driver that might lie outside that zone and soon exploit the bottom line benefits with a strong focus on that specific driver, effectively driving it into the zone as its potential for improvement diminishes. Low impact drivers, even with a high improvement potential, are less attractive and tend to remain unexploited.

The following question may now be asked: So, why would the modelling indicate key drivers that the experienced personnel cannot see themselves? The dilemma lies in the fact that the spotting of high impact drivers is done with the existing rules-of-thumb in place. It is only by building a comprehensive, integrated economic model of

the business, using sound principles, that one may "improve the vision" of experienced personnel. By heightening the level of understanding of the relationships, one will be able to see new opportunities. Also, "urban legends" and policy constraints often mask the potential performance stars. The modelling process assists one in highlighting the constraints induced by policies and urban legends, and consequently allows the real stars to become visible.

Figure 4.2e depicts the process of selecting key performance drivers. The levels to be involved refer to the levels of management. Level 2 refers to the supervisory level; level 3 to middle management and level 4 to senior management. Notice that at least two levels need to work at a step to develop a level of alignment amongst the echelons of the company.

### KPD DEVELOPMENT PROCESS    LEVELS to be INVOLVED

| KPD Development Process | Levels to be Involved |
| --- | --- |
| IDENTIFY PERFORMANCE DRIVERS | LEVEL 3&4 |
| PRIORITISE PD's | LEVEL 3&4 / LEVEL 2&3 |
| DETERMINE % POTENTIAL FOR IMPROVEMENT | LEVEL 2&3 |
| CALCULATE % LEVERAGE | |
| IDENTIFY KPD's | LEVEL 3&4 / LEVEL 2&3 |
| REVISE DRIVERS of KPD's | |
| ALLOCATE RESPONSIBILITIES | LEVEL 2-4 |
| MONITOR PERFORMANCE ← DEVELOP CRITICAL TASKS/ PROJECTS | LEVEL 2-4 |

**Figure 4.2e. The Key Profit Driver Development Process** (Palabora Focus Model, 1995)

The steps described in the paragraphs above, where the creation of the performance model is outlined, allude to the first step in the diagram. All the performance drivers in the model are input to the prioritising step.

## (i)  Prioritising the performance drivers

FOCUS® offers the capability to perform a variance analysis of all performance drivers in relation to any higher parent node. A variance analysis relative to the root node provides a complete analysis of what the percentage impact is on the bottom line of the organisation for a one percent change in any of the performance drivers, respectively.

The output is a list of all the drivers with the ranking's and individual drivers' impact on the bottom line. This list often provides for some interesting team discussions as they try to align perceptions with the analysis results.

The top drivers, now called key performance drivers, are selected for the input of the next step.

## (ii)  Determining the potential for improvement

To complete figure 4.2d, it is important to determine the percent improvement potential. Establishing this could easily turn into somewhat of a dubious art if the goal is just to compile a list of figures and nothing else or the process is not managed properly. Engaging the operating teams in an analysis of why the potential exists, as well as crosschecking it with the performance model, provides further refinement of the structures. The key question to be asked is: Consider each key performance driver – if you had unlimited resources and time, what improvement would be possible by focusing on that driver only? After an answer is agreed on, the probability is considered to discount for the fact that there are indeed limited resources.

The commitment gained from personnel to achieve results with the improvement model is another likely important spin off. The approach to this step is clearly not a number exercise only but a change management opportunity.

## (iii)  Determine monetary value and select Key Profit Drivers

Consider a variable called say, Mill throughput. The data known for this important driver are as follows:

- **Ranking in the list of drivers:** 3$^{rd}$

- **% Impact on Bottom line is 0.4%:** i.e. any 1% change in mill throughput will affect the corporate profit by 0.4%

- **The potential for improvement is 3%:** - this figure is based on discussions with the milling and flotation team

- **Corporate profit for the planning period:** R500m

The monetary impact of this variable is:

**3% improvement potential x 0.4% per % improved x R500m = R6m profit**

Assuming a profit margin of say 20%, this translates into R30m revenue due to the change. This calculation is executed for every key performance driver. Ranking the results provides a list of what is called **Key Profit Drivers**. These drivers are the "stars" that all in the organisation focus their attention on, not neglecting to manage the other performance drivers with the diligence they deserve.

## 4.2.5 Leveraging the model for Value

There are a number of applications for the profit driver model in resource companies, namely:

### (i)    Corporate-wide alignment programs

One of the applications is to align organisations around the core business process. The program described in the paragraphs above will start an alignment programme from a zero-base. The business objectives, strategies, policies and business processes will be subjected to scrutiny through a team approach.

Although the modelling may be seen as overly reliant on numerical analysis, the program will not be successful without a strong change management element. Teamwork is a fundamental component, which ensures that the insights developed through the process will become part of the day-to-day business

approach to problem solving.

## (ii) Continuous improvement projects

The sustained improvement of day-to-day business essentially continues where the alignment programme ends. The only addition is to institutionalise the improvement process. The key driver selection process described above establishes a sound basis for focused improvement projects. Assigning accountabilities to the respective improvement initiatives and establishing the collaborative processes to ensure inclusive teams to take responsibility for achieving results is the next activity.

An important step in rolling out the projects is to ensure that the synergies between the improvement initiatives are clear to all the teams. Teams will almost without failure start optimising their respective micro-environments, resulting in duplication in expenditure, effort and time. Regular feedback among the teams is thus required to ensure that complete value-chain thinking is sustained.

## (iii) Investigations of business options

Issue analysis using the issue trees or maps offers a great mechanism to perform study business options, especially where complex alternatives are available.

## (iv) Framework for studying value-chain optimization

There is a dire need for a framework that makes the downstream effects of mineralogical aspects visible. Traditionally, feedback loops were established within process circuits to stabilize specific processes through automation technology. These automation projects are fine examples of local optima that do not consider (nor have them to function properly) relationships external to that micro-world it is controlling.

A kind of feedback-loop thinking has to be extended across the value chain to enhance the understanding of the downstream impacts of geological information. Due to the long time period and the dearth of interferences between the

upstream driver and the downstream effect, this functioning would, however, differ from automation. In this case, the information will not automatically change a valve or pump speed but would rather be an alert to the downstream operations people who would then be in a position to prepare themselves for the effect of changes in mineralogy.

A Focus® model like this is ideal for assisting in considering the options that exist in certain new situations, as was the case with the backwardation situation described earlier in this study report.

## 4.2.6 Secure a basis for continuous improvement

If the project approach and model were to be adopted by the organisation as a Value-adding process, necessary to maintain alignment and focus, a few additional steps are required. These steps would be aimed at managing the process of continuous improvement.

- A typical outcome is that the organisation's **information system landscape** is fragmented. As a result, information system overlapping, redundancy and data duplication degrade the quality of decision support information. A common problem is the manual reconciliation and massaging of data between systems, which destroys any chance of auditing the quality of the information.

- Changes in the **strategic** and **tactical planning process** as described below become necessary since the model now becomes the hub of the process.

- A change in the **reporting system** to reflect the new targets vs. actual performances, variances and improvement projects through the new unified business context is necessary.

- The mine planning and execution systems, which usually are separate to the rest of the value chain, become part of the complete picture. The same for the marketing and distribution functions. This **integration** will be driven by the

resolutions from studying the model and the adapted business planning process.

### 4.2.6.1 Redesign the business planning process

One of the benefits of the program is that strategic planning can happen at more regular intervals. The model becomes a vehicle for assessing whether the monetary strategic objectives are achieved. Corrections to the strategic actions could be made more regularly. No longer is it necessary to make strategic decisions based on normal business reports only but with the addition of an integrated business performance model.

The business model needs to be incorporated into the business planning processes as it becomes central to the strategic thinking, the performance assessment process as well as the continuous improvement planning and monitoring program. It regularly refreshes the complete list of "rules-of-thumb" in the context of the strategy and varying conditions.

### 4.2.6.2 Identify and train personnel

The model should be maintained, and information derived from the trends that are identified by the model. A person with both business and modelling background has to take ownership of the model. The respective divisions and departments also need a person skilled in the maintenance of business models and issue analysis. This person should ideally be close to the CEO and act in an advisory capacity, also to ensure maximum co-operation in keeping the business model alive and operative.

### 4.2.6.3 Regularly audit and improve application

People working too close to the analysis of the business may become uncritical of structures that have been in existence for some time. An outside auditor may be used to great effect in assisting to achieve and maintain a level of objectivity. The term auditor might be easily substituted for facilitator since the external person also need to facilitate a continuous improvement in the application of the model, which is different to what would be expected of the traditional "hands-off" role of an auditor.

# 5  Results

## 5.1  Conceptual Business Model

The following sections present the results of a study conducted at Palabora Mining Company. The study is aimed at illustrating the level of thinking required to challenge the business-as-usual rules.

### 5.1.1  High level value chain process steps
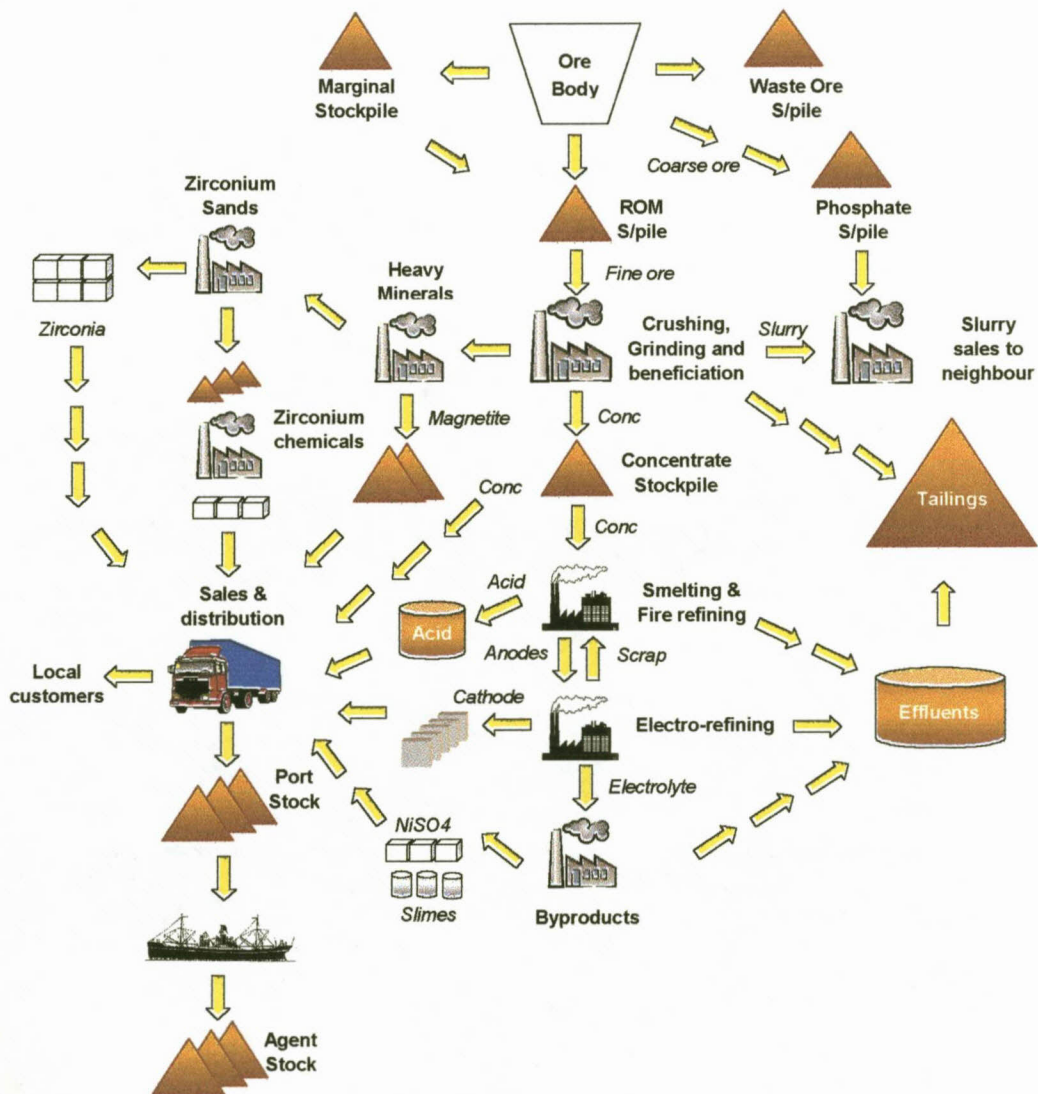


**Figure 5.1a. The essence of the Palabora Value Chain (Palabora Focus Model, 1995)**

Figure 5.1a is intended to illustrate the major steps and process flows in the company value chain into the level that the first pass of the project will take the process. It uses the simple convention of depicting only production, transport, and stockpile processes. This basic diagram is used as the context diagram for exploring processes to further levels of detail, and to understand the boundaries of the value chain.

## 5.1.2 Factors influencing business

The prevalent issues were grouped as follows:

(i)     Mining & ore grade economics

(ii)    Concentrator

(iii)   Smelter & refinery

(iv)    Marketing

(v)     Cost structure

(vi)    Management

This study is not aimed at addressing each of the issues raised here since many of them exhibited variability or became subject to or even part of other issues during the study. Each of these was expanded and as insights were gained, bulleted notes were added to start the discussions and solicit inputs from the various players.

### (i)     Mining & ore grade economics

- How are cut-off grades calculated? How often should they be calculated?
  - Principle: value at 0.1%Cu should be nil as this equals the highest tailings grade.
  - To be established: What is the volume of the rock in the cut-off domain i.e. -50% to 100% of cut-off grade? Very little. Due to the current operating level in the pit where most of the ore is above cut-off grade. Also due to the clear distinction between dolerite intrusions and the ore.
- Intermediate ore grades stockpiling.
  - Stockpiling of 0.05 - 0.1% Cu ore not possible - discrimination between ores too difficult
  - Intermediate stockpiles: 0.1 - 0.15% Cu ore is stockpiled

- When should existing marginal ore stockpiles be treated?

  o *Processing of marginal stockpiles should be postponed as long as possible. Treat only when having to and if the market conditions will allow for profitable processing of the marginal ores.*

- Should the strategic stockpile be converted to crushed ore in times of spare capacity at in-pit crusher?

  o *Play off: <u>costs</u> will be at the in-pit crusher, at the conveyor and by hauling on the surface against <u>savings</u> will be in ramp hauling and reloading of the crushed ore.*

- Should one have a surface (crushed?) ore stockpile to reduce mine life at the expense of stockpiling costs?

  o *Find the next best stockpile location. This option could also facilitate ore blending. Weigh up the savings in Fixed Costs against the cost of double handling by mining faster.*

- Is it possible to blast and crush finer? If so - how fine. Alternatively, can one use the spare primary, secondary, tertiary or water flush crushing capacity for finer fine ore?

  o *Evaluate the savings in milling costs and higher throughput rates at milling against the higher blasting costs.*

## (ii) Concentrator

- Where is the bottleneck for sales? And for shareholder wealth? What is the economics of using water flush crushers in the circuit as proposed for the underground mine? This may be done in order to reduce mine costs for segregating dolerite and to improve conventional circuit performance.

- Selling vs. Processing concentrates: Possible alternatives are:

  (i) *Selling now vs. smelting and refining later.*

  (ii) *Selling now vs. smelting and refining now - i.e. invest capital in smelter upgrade*

  (iii) *Stockpiling to sell later*

  o *Also consider effects of backwardation, sovereign risk effects.*

- Can we improve the recovery by knowing the mineralogy before it enters the milling section? What is the effect of the expected increase in variation in Cu feed grades?

  o *i.e. get more precise information on the mineralogy from the pit.*

  o *Or measure mineralogy in the milling and flotation circuit.*

- What is the optimal mill throughput rate and concentrate grade? If variable, what are the drivers for decision-making?

  o *Consider the respective impacts of Cu price, recoveries, fixed cost periods and impact on smelter.*

    o  *How is the smelter affected by concentrate grades?*

- Should the mills be run flat-out (i.e. producing concentrate faster than the reverberatory furnace can consume) until end-of-mine life? What is the cost of stockpiling concentrates including wind and rain losses and contamination?

- What is the relationship between the size distribution and the recovery of the by-products like zirconium? What is the optimum size distribution vs. the total product contribution?

- Identify the magnitude of the opportunity to keep dolerite out of the mill feed?

    o  *Every ton of dolerite displaces 3 to 4 tons of good ore.*


## (iii)   Smelter & Refinery


- What are the monetary benefits from mixing concentrates before reverberatory furnace smelting to establish an even matte grade?

- Evaluate smelting reverts directly or to upgrade (milling and flotation) first before re-smelting in the reverberatory furnace?

- Should the anode scrap and other stockpiles be treated or kept in stockpile until later? What would be the effects of backwardation?

- Smelting and refining reverts, sorted or unsorted, or converter slag in a new smelting furnace.

    o  *Unlikely because of the possibility of treating it in the reverberatory furnace. Treating the converter slag is the preferred option.*

- Can we use the market backwardation argument to strengthen the case for a new Smelting Furnace?

    o  *What is the effect of a shortened ore-to-metal life cycle?*

    o  *How often does backwardation occur?*


## (iv)   Cost Structure


Consider the split fixed costs by purpose:

- Compulsory part of business.

- Service to assist line management.

- Cheaper than facilities management.

As opposed to:

- Sensitivity to volume effects, i.e.:

- (Insensitive, affected by # of shifts, dramatic change in volume).

### (v)   Marketing

- Investigating buying concentrates from neighbouring organisation exploiting a different ore zone in the same ore reserve.
  - *Leverage economies of scale and share in saving the concentrate transport cost per ton Cu as oppose to lower transport cost of pure cathode metal. Consider the difference in mineralogy of the concentrates.*
  - *What TC/RC's (TC=Treatment charge; RC=Refining charge) can we expect from buying neighbouring organisation's concentrates?*
- What is the difference in profitability between the various sales regions? Where does the most value-adding take place, referring specifically to by-products?
- Why not convert all cathodes to rod and export rod instead of cathode?
- Determine the split of all selling expenses between cathode and rod.
- Price determination: How is the rod price determined?
  - *Issue: import vs. export price parity. Is the price based on delivery to nearest LME warehouse?*
- What is the import parity price of the rod? And for cathode? For rod it should be something to the tune of:
  - *LME +*
  - *(Singapore/Europe) casting +*
  - *(Singapore/Europe) transport to RSA.*
- Should Marketing/Sales focus on both sales /sales admin and moving to obtain a conversion charge closer to import parity:
  - *(Current conversion charge - export parity)/(Import Parity - Export Parity)*

### (vi)   Management

- What are the correct transfer prices and accountabilities / performance measures to ensure that divisional management is driven to site optimum decisions whilst taking a division specific view?
  - *Transfer prices could communicate process economics. e.g. consider approaching the divisions as a supply chain joint venture where products are bought from the upstream department. Could we do something similar between the mine and the mill to reflect mineralogy uncertainties?*
- Determine an effective implementation strategy for post-project evaluation.
- Evaluate the value of creating potential going concerns.

The outputs from the core process flow analysis, the business environmental scan in the previous sections and the issues above shape the rough-cut profit driver model discussed in the next section. An important motivator for the program remains to address the key business issues through team alignment.

### 5.1.3 Rough-cut Profit Driver Model

The initial Palabora business model captured a few critical views taken on business. This is the first exposure the management team got on how this approach differs from business-as-usual thinking. The fundamental views taken in the model were:

- The **complete value chain had to be included** into the model. The sales and marketing division was off-site and as a result, the value chain was not visible to all decision makers. The fact that the mining division operated autonomously with separate systems, stores and workshops made it particularly difficult to get an integrated view of the complete chain.

- As discussed in section 3, the **contribution approach** to management accounting has become a preferred approach over the traditional absorption for the modelling process (Sylvester, 1995). His motivation stems from the fact that each contribution can be subdivided into underlying contribution calculations by playing off revenues or benefits against costs or penalties. It also augured well for using separating out production volume and unit rates of profit and costs, which is the basis of the business modelling process.

- Comparisons of alternatives **on the basis of contribution to the bottom line** of the company formed the basis of the issue maps drafted during the project. To do these comparisons the cost and throughput information must be standardized and in the appropriate format. This was not the case at Palabora since the various disciplines require different perspectives of the data. To get to a business model all relevant data were to be unified along the same (economic) perspectives.

- The **value-add for each of the respective operating business units** in the value chain was not clear at Palabora due to overhead allocations and the absence of a true product costing approach. Some of the by-product revenues were added into the copper production costs, making it difficult to understand the impact of variations in production. The product costing approaches therefore had to be revised. A basic premise of the model was that it **should be clear where value is added to ensure that everybody focuses attention on the constraint in the value chain**. Goldratt (1990) thinks along similar lines when he suggests that as soon as the constraint in the production chain is defined, everything should be subjected to that constraint.

- Concerns from the financial division about the integrity of the financial information in the model led to a decision to reconcile the model financial information with the financial statements. This turned out to be an important step as it highlighted the **discontinuity in the layers of operating and financial reporting** systems. More about this later in this document.

- An attempt to highlight more **causal links** was hampered by the absence of the former research and development section. As such, interrelationships between production parameters were therefore based on rules of thumb that were not revisited from time to time. Two examples are the impact of dolerite and magnetite on milling throughput, and of concentrate grade on smelting throughput. The lack of accuracy lost through poor sampling practices and the time it took to determine the mineral composition also worked against researching further causal relationships. Perhaps it is also because factors other than the mineralogical and chemical often dominate the decision making process like the production targets determined the previous year, based on the mine information available at the time of planning. However, as business processes, information systems and people's behaviour became progressively more integrated, the relationships between chemicals at the furthest downstream end with the specific areas mined became easier to see.

Figure 5.1a illustrates how the model is structured according to the contribution approach to accounting. The nested layers of performance drivers reflect the layers in the driver hierarchy. In the model the structures are represented by formulae describing the relationships between the layers of profit drivers. For example, the figure below should be read to mean:

Profit (short-term effects) = True marketing Value-added plus…

Site Value-added less…

Corporate costs and then…

Adjusted for stock adjustments and accounting corrections. This connectivity applies throughout the model, from the root node to the deepest layers of the tree, the ">>" indicating that the tree will expand further.

```
1. Profit (short-term effects)
        1.1 True Marketing Value-added
            1.1.1 Marketing Value-added - Actual
                1.1.1.1 Marketing Value-added – Rod >>
                1.1.1.2 Marketing Value-added – Cathode >>
                1.1.1.3 Marketing Value-added – Concentrate >>
        1.2 Production Site Value-added
            1.2.1 Smelter & Refinery Value-added
                1.2.1.1 Total Contribution
                        1.2.1.1.1 Unit Contribution (Cost Tree)
                            1.2.1.1.1.1 Cathode Economic Value >>
                            1.2.1.1.1.2 Unit Variable Costs >>
                        1.2.1.1.2 Volume Produced (Volume Tree) >>
                1.2.1.2 Fixed Costs >>
            1.2.2 Mining and Milling Value-added >>
            1.2.3 Unallocated Site Overheads >>
            1.2.4. Allocated Site Overheads >>
        1.3 Stock Adjustments >>
        1.4 Accounting Adjustments >>
        1.5 Corporate Costs >>
    2. Long-term business impacts >>
```

**Figure 5.1b. The high level structure of the business model  (Palabora Focus Model, 1995)**

Further explanation of the model is required to make sense of it. Contributing to corporate profit are mainly two factors, namely, **short-term profit** and **long-term impacts on profits** (refer to points 1 and 2 in fig. 5.1b). The former provides a short-term profit-based analysis of the business, illustrating how value is added through the process steps using the contribution accounting approach for an accounting year. Considering the full LOM period, the long-term impact on the

business due to market (pricing) conditions and controlled changes in throughput is accounted for as an adjustment to the short-term view of the business. *The long-term view therefore adds a strategic dimension to the business model and will be discussed in more detail below.*

The short-term model deserves attention first to clarify the principles to the reader. Refer to point 1 in fig 5.1a. The short-term profits are affected by:

- **Value-added by marketing** (1.1) through selling copper concentrates, cathode and rod. The sales of the by-products like nickel sulphate, anode slimes, zirconia, magnetite and others have, however, been accumulated within the Site Value-added branch of the tree. This was merely due to the project brief which stated clearly that only the core copper process should be modelled at first, not neglecting the impact of by-products. Should the project be extended to the modelling of the by-product streams as well, it should be moved to the Marketing Value-add branch.

- **Value-added by the site** (Mining, Concentrator, Smelter and Refinery) (1.2) A detailed description follows in the next section.

- **Stock Value Adjustments** (1.3): The **stock** is valued at the economic value of the respective products, as well as the values determined quarterly by the accounting department, since both valuations are useful. *The economic value is determined by the official market price of the commodity (e.g. LME-price) adjusted by additional costs like penalties, charges and transport, therefore, on a delivered-at-customer basis.*

- **Accounting Adjustments** (1.4): the profits derived from the profit model are adjusted to match the official income statement. This step is necessary because of the deviation from traditional accounting procedures in the valuation of copper stocks in the business model.

- **Corporate overheads** (1.5) mainly reflect the costs of the management function, which was situated in Johannesburg and operating as a separate legal entity.

Refer to 1.1 - **Marketing Value-added**: The question to be answered here is: How do the marketing activities add value to the products from the operation? The

respective products can be sold at the economic values of each respective product or can, by using marketing expertise, be sold at a price that increase the value to the producer.

The approach with **the Rod Marketing Value-added tree** on the one hand, and the **Marketing Value-added for Cathode and Concentrate trees** on the other, are worth further discussion. With the latter two, the marketing department adds value only through the traditional marketing process. No form of further processing of products is included in these two tree structures. In the Rod-tree model, however, the value is added through a joint venture-agreement under, which the cathode is converted to rod, therefore includes a physical process. It captures the Value-added by the marketing department by negotiating the charge with the joint venture partner. The opportunity exists for the evaluation of the costing of the different rod sizes so as to encourage clients to convert into less costly sizes. The cost of cobbles, which is when the copper cable becomes entangled in the rod milling process, as well as the mill changes, could be used in the Modelling process.

Refer to 1.2 - **Site Value-added:** Again one can see the play-off: the Value-added by the site is a function of the Value-added by the operating divisions minus the site overheads. The Value-added is a function of the variable and fixed costs as well as tons produced which, in turn, is a function of the key performance factors underlying the structures. *The art of structuring the trees is in finding the right performance drivers through analysis and through reaching consensus with the relevant personnel.* Also critical is the definition of the key profit drivers for measuring performance to aid in optimising site performance. FOCUS® provides the platform on which these drivers can be identified, prioritised and monitored. More about the actual structures in the section covering the extended model.

With this improved understanding of the short-term effects, one may can turn back to the long-term impacts under point 2 above. Under normal circumstances, changes in mine throughput changes the remaining life of the mine. As a result of the open pit mine approaching of the end of mine life, this impact of the *duration* of the remaining mining period on decision-making becomes progressively larger. In reducing the number of cost periods, the total fixed costs for the remainder of the

(shrinking) period are also reduced, an impact that becomes progressively more dominant in the profit calculation.

In addition, higher throughput would move sales from the end of mine life towards current sales. The earlier sales lead to earlier cash flows; therefore, less interest cost or more interest earned. At the same time, future sales are foregone (or moved out of future sales into current sales) and hence, the forecasts for the last operative year should reflect such reductions.

All the long-term changes in throughput are offset against each other and should be reflected as such in the model to understand the combined impact. The short-term profits are subsequently adjusted in point 2 to reflect the effects of changes in the throughput rates through the complete value chain.

There are other important consequences of adjusting throughput rates through the concentrator. The effect on residence time, and therefore on particle size and recovery is also modelled, but not as part of the long-term effects as discussed later in this section.

The two long-term driving forces behind the adjustment of the short-term profits that reflect a long-term wealth creation objective, are:

**A. Mill Performance sub-tree:** Refer to the Mill performance sub-tree in figure 5.2g. Keeping the modelling design principles in mind, a play-off is made within the Mining and Milling part between the increased concentrate production and decreased recovery with an increase in the milling rate. The progressively lower concentrate grade with increased throughput is sufficiently modelled by the reduced recovery *on proviso* that the concentrate grade is still within saleable specification, and not incurring penalties for deleterious elements. Cases that fall outside the operational control set points are not modelled until they become an option, for instance, to produce off-grade product, etc.

The driver behind the model is an empirical 5:1 ratio between throughput and recovery. The complex relationship between mineralogy and recovery on the one

hand and, to a lesser extent, throughput and recovery, is still largely affected by other poorly understood parameters like particle size contribution, reagent dosage, etc., and therefore yet not fit for business modelling. The benefits of improved clarity concerning these relationships should be of great value to optimising wealth creation; certainly a subject for further research. Nevertheless, the 5:1 ratio is used to assume a 5% throughput rate increase and hence, a 1% decrease in recovery. The value lost in tailings as a consequence of lower recovery to concentrate, is calculated and offset against the increased revenue from sales due to more concentrate being available.

The contribution from the increased current sales of concentrate is calculated by taking the effect of backwardation into account. The backwardation level (viz. the difference between the <u>current</u> spot price and the base price as implied by the futures price – referred to in section 3) is offset by the amount of contribution that could be realised through smelting and refining of the concentrate. Importantly, this contribution is a function of the (lower) price that will be realised <u>after three or more months</u> due to the processing time. The differential therefore quantifies the additional value that can be realised through selling concentrate, under backwardation, above the value that can be added to the concentrate through further processing. Also note that the reduction in mine life through increased throughput rates could cause a reduced total fixed (period) cost that has to be added to the value through increased sales.

*The combined effects of the throughput-recovery and the sales-backwardation-mine-life parts of the performance tree provide a simplistic though thought-stimulating result.* The potency of the model can be enhanced greatly by better information (second order relationship curves rather than straight line relationships) on the performance relationships.

**B. Smelter & Refinery Model sub-tree:**

Refer to the Smelter performance sub-tree diagram in figure 5.2j. The Smelter & Refinery division is the profit bottleneck (refer discussion of bottlenecks in section 3) for the organisation. This essence of the explanation is that the smelter is

constraining the short-term profitability of the organisation as it prevents value to be added to the concentrate in turning it to copper metal.

The Smelter and Refinery sub-tree in general reflects the reality that, should it be necessary to increase actual cathode sales due to a backwardation situation in the market, it might be done at the cost of reduced maintenance. The production rate cannot be sustainable under this kind of short-term pressure to maximise production.

Thus, setting off the natural tendency to drive for maximising throughput against the long-term effects will illustrate the net effect, which, considering all the other relevant effects, might be less attractive. The model helps one to collate the multitude of economic and operating variables into an integrated structure that presents the net effect. Strategic planning can now take place based on more inclusive, integrated information.

In both the above sub-trees, a base production rate is introduced to reflect the normal production plan. Any manipulation of the performance drivers will cause production to vary from the design (referred to as "base" throughout this document) production rate, indicating the variance relative to the base production rate.

The next section describes the enhancement of the model structure described here to include all strategic planning periods and expands the issue maps to the point where the best alternatives become clear. The key profit drivers, potential for improvement, as well as profit leverage, are calculated. A focussed continuous improvement programme is developed from these outputs.

## 5.2 Refined model

The extended model improves the extent and depth of the initial model, taking it beyond its initial use as business-engagement facilitation support. This section will highlight special aspects of some, but not all, of the main "branches" of the tree in order to substantiate the modelling principles.

Attention shall be paid to explaining the approach, as well as the depth and power of the model rather than attempting to expand on all the issues covered during the project. The aspects covered should be sufficient to form an understanding of how this unique combination of processes and analysis tools will support the management and optimisation of a mineral resource.

## 5.2.1 Extended model

Refer to fig 5.2a below for the top-level view of the profit tree. It breaks the long-term profit up into (i) a short-term profit and (ii) the long-term play-off as discussed in the previous section. The third branch i.e. "Management Information" contains the derived issue trees, as well as a data capturing area to simplify the initial data take-on before the process is automated. This branch is disaggregated from the profit tree and as such, it does not have an impact on the bottom line profit.
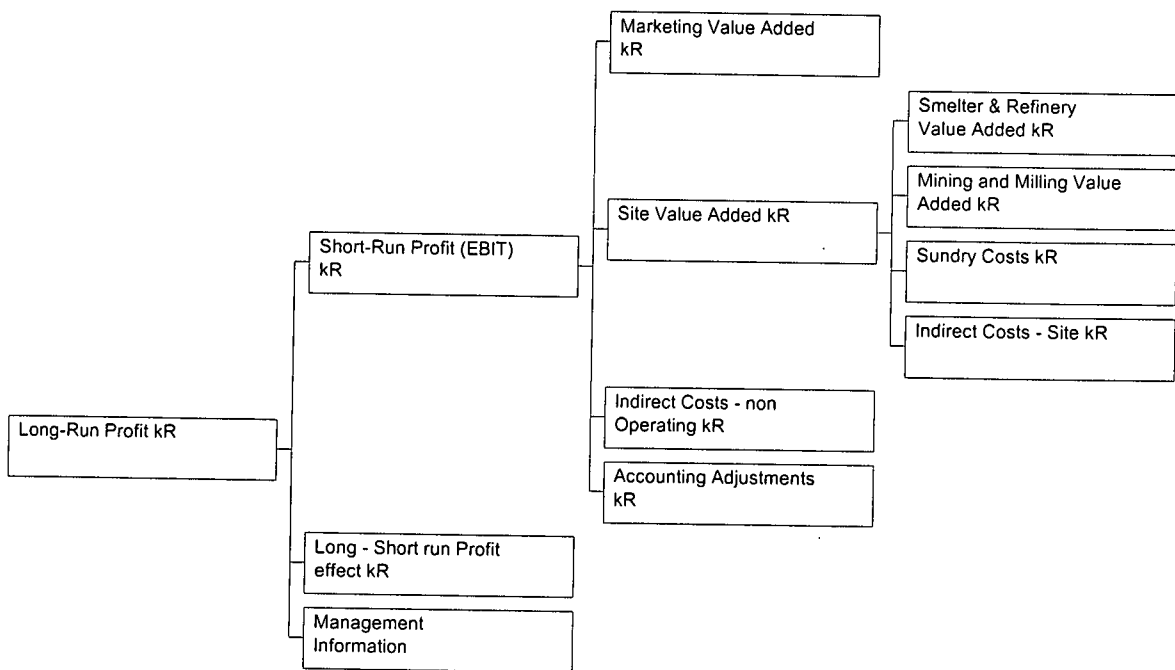


**Figure 5.2a High-level business model (Palabora Focus Model, 1995)**
**(kR = R'000, EBIT = Earnings Before Interest and Tax)**

The short-run (renamed to "short-term" which is a more common term) profit consists of the Value-added through the mining site plus the value from the marketing process, adjusted for stock variations, less the corporate and overhead

costs. As mentioned before, a reconciliation branch had to be constructed to reflect the differential between the Focus® model and the accounting system. Taking the right-most nodes further one finds an extensive structure underneath it that enhances one's understanding of what drives the business.

## (i) Marketing Value-Add:

The Marketing Value-Add branch separated the various copper product formats out to illustrate the Value-added to these products by means of the respective marketing activities. The complexities that have bearing on the copper rod products, which add particular value in evaluating the Value-added in the joint venture. Figure 5.2b shows the high level breakdown that clarifies what PMC and TCRC (Palabora Mining and the joint venture company called Transvaal Copper Rod Company) contributed to the final Value-added to the cathode from the refinery.
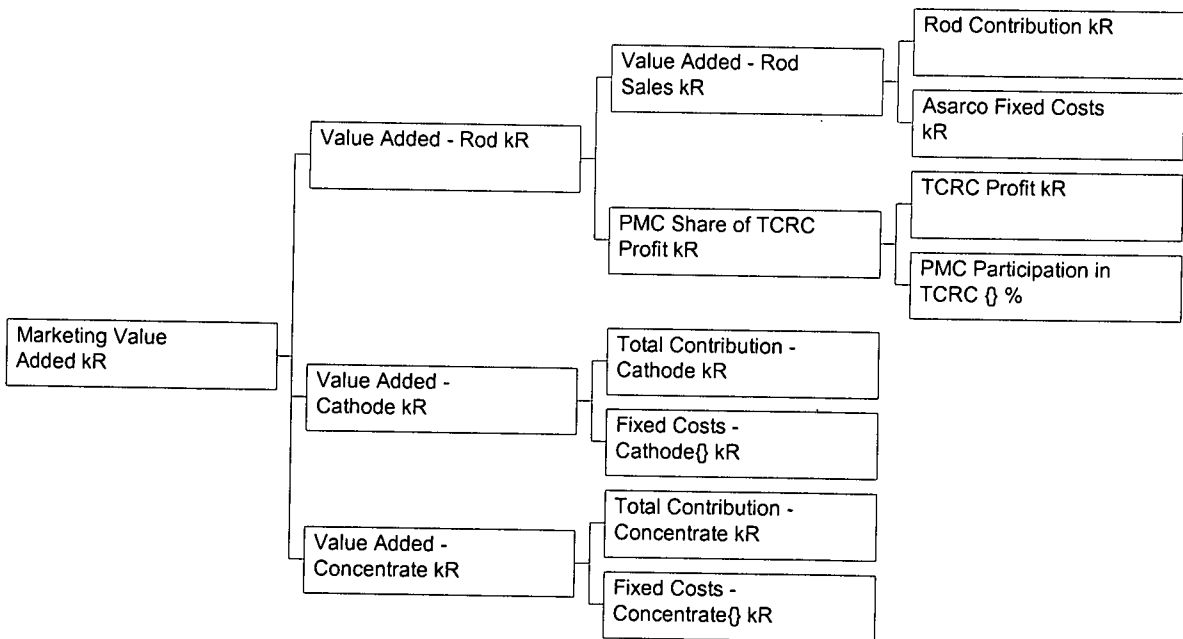


**Figure 5.2b Marketing Value-add Tree Layout (Palabora Focus Model, 1995)**

( {} at the end of a node description indicates it is the terminal node, hence cannot be expanded further)

The Value-added through rod production and sales is split according to the shareholding in the joint venture.
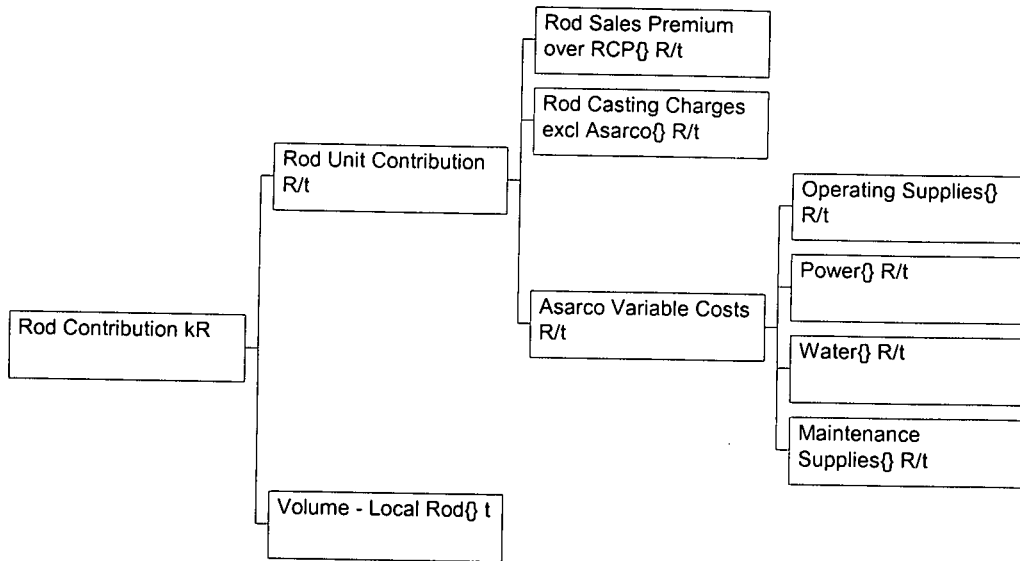
**Figure 5.2c Rod total contribution construction (Palabora Focus Model, 1995)**

Figure 5.2c shows how the Asarco smelter costs, which were an internal charge to the company, are discounted first from the total contribution. Subtracting the internal Asarco variable costs from the income (before charging the joint venture company) and from the premium over the Republic Copper Price (RCP), yields the unit contribution. This RCP is the price that Palabora determines for copper metal in South Africa.

The actual economic value of the cathode is substituted for the RCP in this branch to reflect the true value-added as rod is marketed only within South Africa; thus, the economic value of cathode will not be a true reflection as it represents the delivered price at the LME (London).

Moving down a level the rod value-add branch (fig. 5.2d) reveals what is driving the total contribution through the rod stream.

One can appreciate how these structures allows the company to plan and monitor the performance for this branch with amongst others, using the Profit Trends View (fig 5.2e):
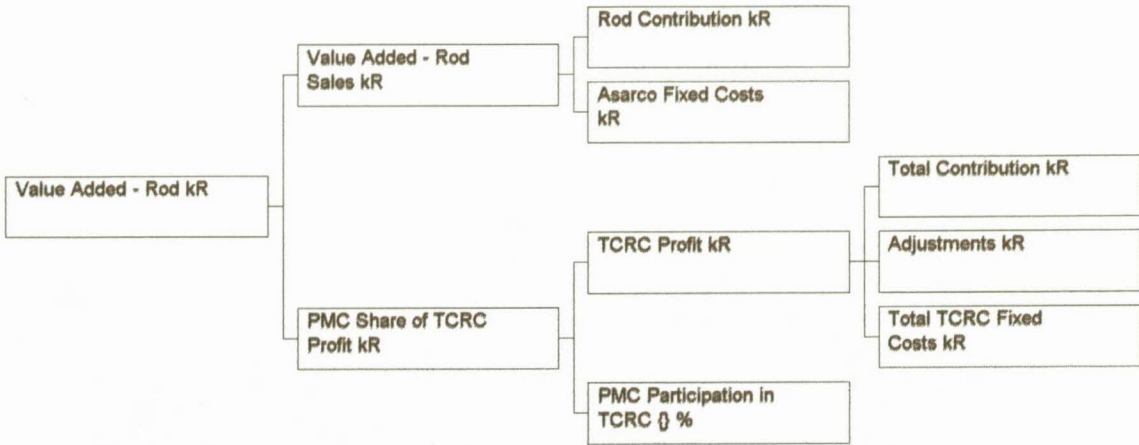
**Figure 5.2d Rod Value-add construction (Palabora Focus Model, 1995)**
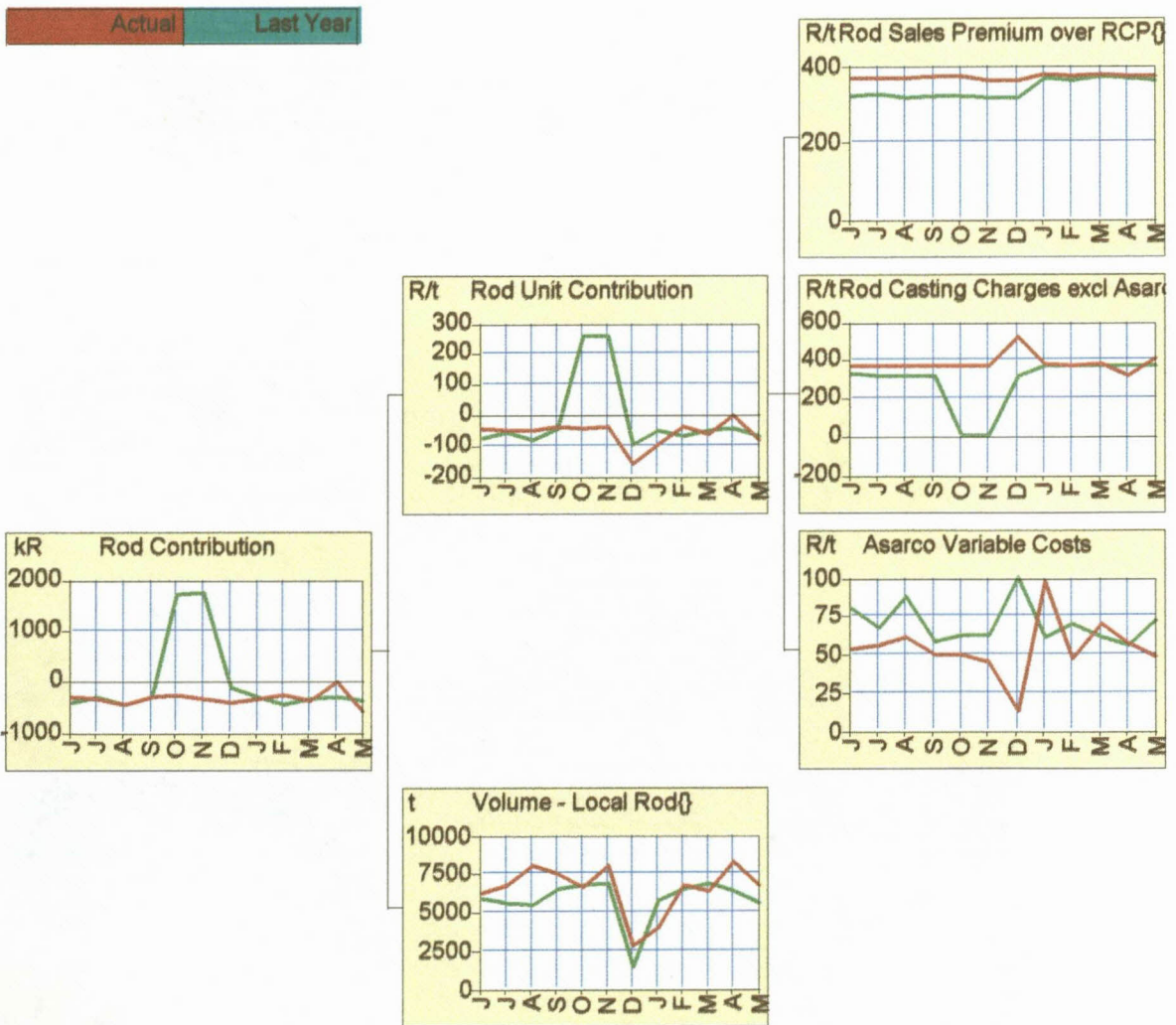


**Figure 5.2e Profit Trends View of rod contribution (Palabora Focus Model, 1995)**

In this view not only the relationships, but also the trends are shown. The use of mutually exclusive and completely exhaustive formulae, enables the trends in the leftmost node to be explained by the nodes to the right of it. This applies to all levels of the model. The high rod contribution in the months of October and November is explained by a similar two-month increase in **unit** contribution (and not by volume). Moving further to the right one can see that the correlating two months show no costing charges and is probably an accounting aberration and of no specific concern. An adjustment in the model will remove the "noise" from the business model.

## (ii) Site Value-add:

The Site Value-add branch covers the complete internal value chain from the open pit to the final products as shown in figure 5.2f:
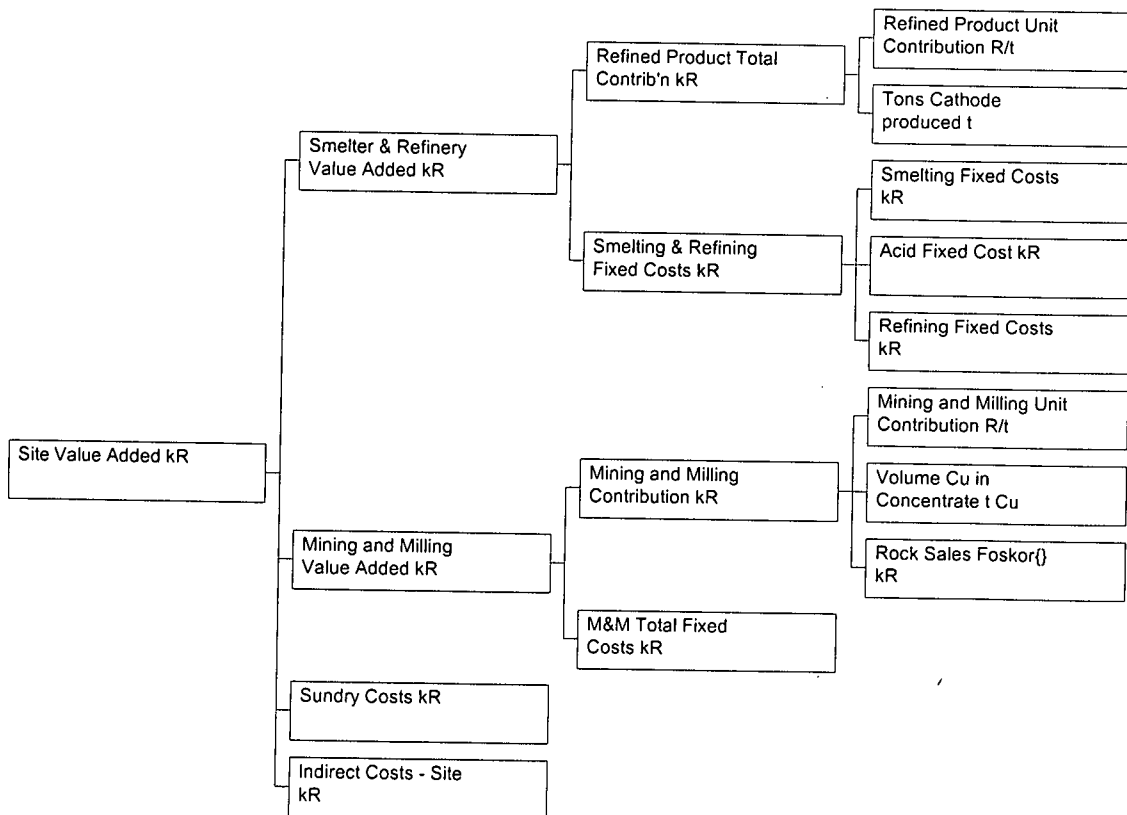


**Figure 5.2f. The Site Value-add Construction (Palabora Focus Model, 1995)**

Note that the structure of the Site Value-add branch is based on the following tenets:

- A Value-add-branch can only be based on a <u>saleable</u> product, hence a product with economic value, i.e. the London Metal Exchange Price less the un-accrued costs to make it saleable (refer section 3). Mined ore is not such a product; according to this definition the mining and beneficiating plants deliver a saleable concentrate and are therefore combined into one value-add section.

- The rate at which any value-add section produces and adds value to input materials can and should be off-set against its downstream neighbours' throughput. If the upstream section produces faster than the other a stockpile will grow between the processes (or *vice versa*). By setting up the value-add section components to offset their rates of production and value-add, the constraining point can be carefully evaluated and monitored on an <u>economic</u> basis. Evaluating the constraint in this way ensures that the complete economic picture is visible to the decision makers.

Due to the above tenets, the mining and beneficiation section, and the smelter and refinery sections, respectively, were combined into value-add sections. One of the benefits of combining the mining and beneficiating sections was the visibility of the value chain that it brought about in a traditionally divided planning area.

The "Sundry Cost" and "Indirect Costs" nodes might raise a question as to what the differences are. The Sundry Costs node summarises the depreciation, and internal costs of consuming products from the mine itself like Sulphuric Acid, etc. The Indirect Costs, on the other hand, contain costs from all the support departments like human resources, technical, environmental health and safety, etc.

**(iii) Mining and Milling:**

The clear play-off created in the mining and milling branch is again according to the contribution construction as shown in figure 5.2g.

First, the Value-Add is split into the Total Contribution and the Fixed Cost components. Total Contribution is then broken up in the unit contribution and the throughput volume components. The economic value (similar to price), less the unit variable costs, constitutes the unit contribution. Within the unit variable cost nested layer the Mill and Mining variable cost branches are added to each other. This arrangement requires one to optimise the <u>combined</u> variable costs, so that the effect of saving explosives (and the consequent expected coarser fine ore) can be offset against the higher milling costs (due to a coarser mill feed).
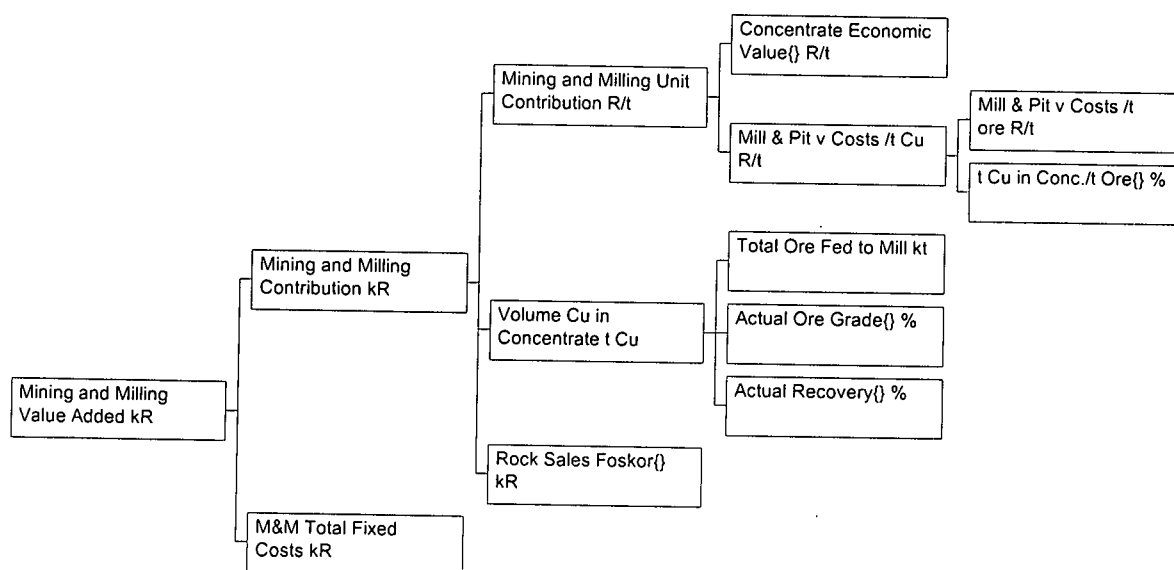


**Figure 5.2g. The Mining and Milling Value-add section (Palabora Focus Model, 1995)**

Following the branch "total ore fed to mill" in figure 5.2g, the combined throughput of the autogenous and conventional milling sections is expressed in the actual expected copper in concentrate produced from it.
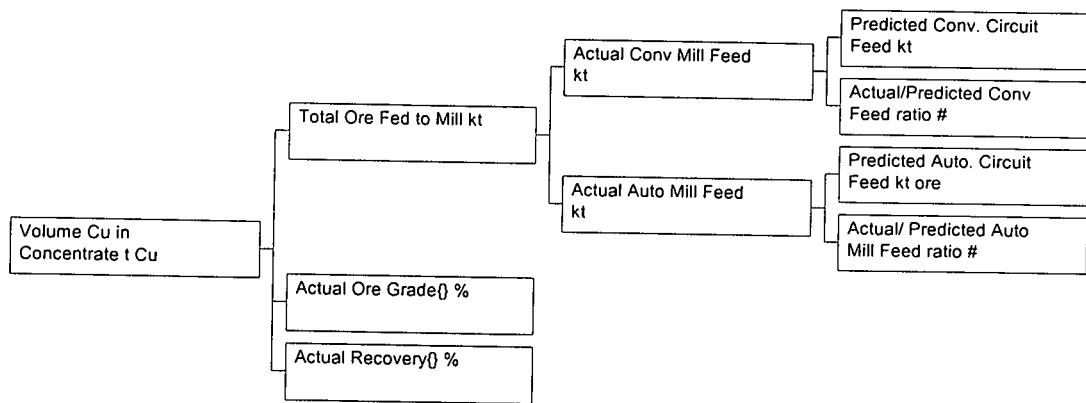
**Figure 5.2h. Drivers of the Volume Cu in Concentrates (Palabora Focus Model, 1995)**

Behind the combined throughput is the key profit driver namely the %dolerite, which originates from the dykes running through the carbonatite ore, and is exceptionally resistant to the milling process. This effect is much less pronounced in the autogenous milling process where the dolerite acts as a natural grinding medium. The %dolerite as well as the availability of the respective mill types, effectively drives the throughput.

The following diagrams from the Focus® model explain how %dolerite determined the throughput. The depth of the model requires that the layers of the model be presented separately for legibility, starting off with the conventional milling circuit drivers (fig 5.2i):
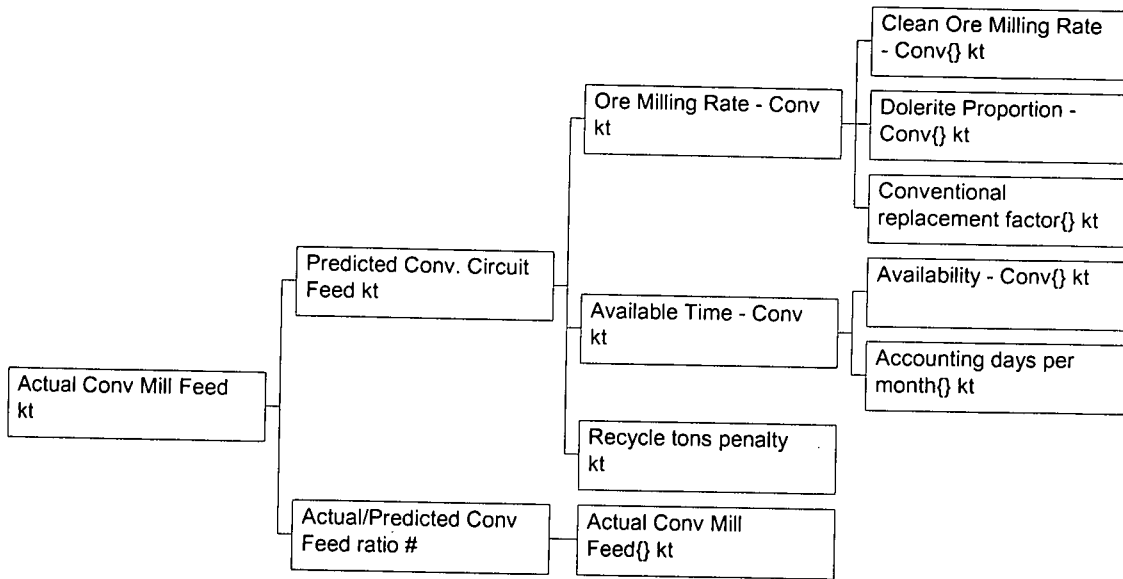
**Figure 5.2i. Actual and Predicted Conventional Milling Play-off Construct (Palabora Focus Model, 1995)**

The effects of dolerite were discussed earlier; figure 5.2i models the effects of dolerite by decreasing the throughput rate expected for a dolerite-free ore according to the actual dolerite levels and the empirical displacement factor. The displacement factor is the amount of clean ore tons less milled for every ton of dolerite in the mill feed ore. The recycled material from the smelter further reduces the predicted milling rate that replaces the clean ore at a one-to-one displacement. These, together with the available milling time, predict the conventional milling rate. To monitor the model, the actual milling throughput is compared with the predicted tons. Any drifting between the two requires one to refine the model or look for changes in the conditions around the milling section that might need to be included into the model. The autogenous milling section functions in a very similar way.

The importance of other effects, such as pulp density, particle size distribution and magnetite content, have become factors for optimising the efficiency of the milling and flotation sections. These factors are considered on a shift-to-shift basis whereas the drivers in the model are of importance in understanding the daily, weekly, monthly, and even quarterly decision-making.

## (iv) Smelting and Refining:

Like the mining and milling sections, these two processes were combined into one, also because together, they produce the next important saleable product. In hindsight one could have, however, accepted the separation of the refinery from the smelter sections, and indeed so for two reasons, namely:

- The smelter and refinery value-add section gain so much "depth" that one tends to lose the thread of the value chain logic when tracking trends are taken down the branch.

- An anode is a saleable product provided there are other refineries with spare capacity around. Selling anodes in times of the refinery tankhouse section constraints could be better evaluated and the cost of carrying internal stock of anodes could be better managed with this information.

A comparison of the Mining and Milling Value-Add Branch and the Smelter and Refinery Value-add branch highlights the considerable differences in depth and complexity that one obtains when modelling a business. The latter branch turned out more complex due to:

- The batch nature of the Smelting, Fire Refining and Refinery process
- The high cost addition steps
- The high levels of intermediate stockpiles and of metal recycling between the various steps within the process.

Figure 5.2j shows the high level construction of the Smelting & Refining Value-Add Section. True to the contribution approach to management accounting, the first level down is to discount the total refined copper product contribution by the fixed costs for this value chain component. The total contribution, in turn, consists of the product of the unit contribution margin and the cathode throughput volume, i.e. the "cost and volume trees".
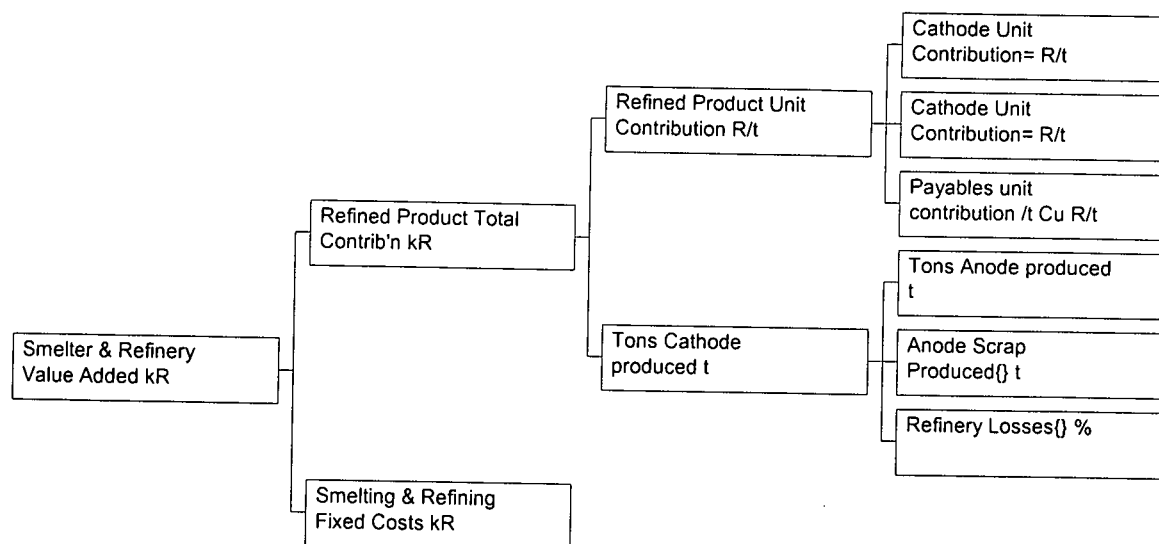
**Figure 5.2j. A high-level structure of the Smelter and Refinery Section (Palabora Focus Model, 1995)**

(Contrib'n = Contribution, R/t = Rand per ton unit costs or contribution)

At this point in the unit contribution structure, a play-off structure has been built up between two views of the Cathode Unit Contribution (I and II). The first, illustrated by figure 5.2k (I), depicts a shallow and simple discounting of the cathode and by-products margin by the total variable costs across the value chain segment. This could be considered a rough-cut view, which provides very little insight in the value chain.

The second figure (5.2k (II)) illustrates the second view, a complete value chain view. With this view every process has been divided into sub-sections. The structure starts at the product end of the value-add chain and then "slices" off the variable costs (VC) one step after the other, until the concentrate, fluxes, coal and other raw material feed are encountered – all adding up to the final products variable cost.
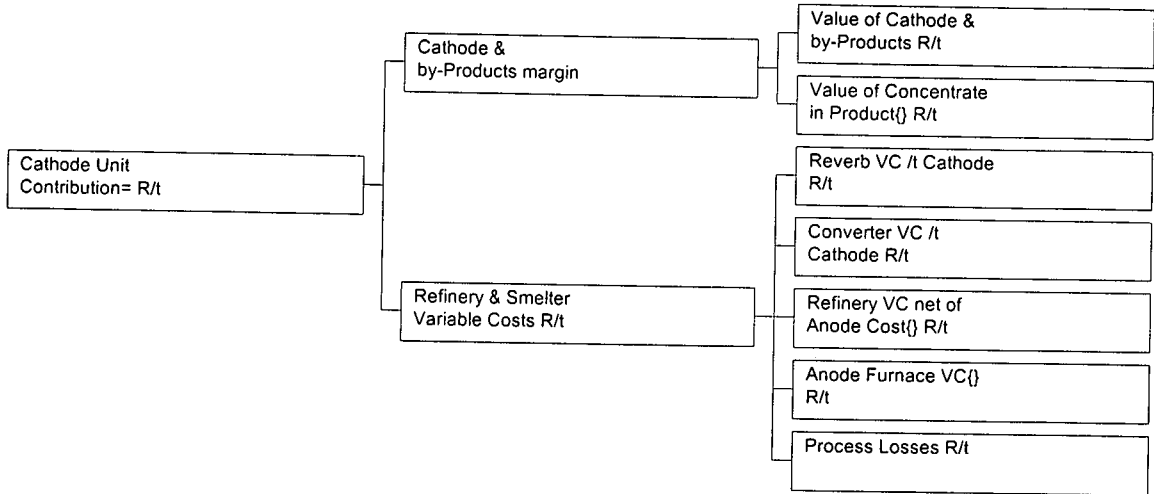
**Figure 5.2k (I). A simple view of the Cathode Unit Contribution (Palabora Focus Model, 1995)**
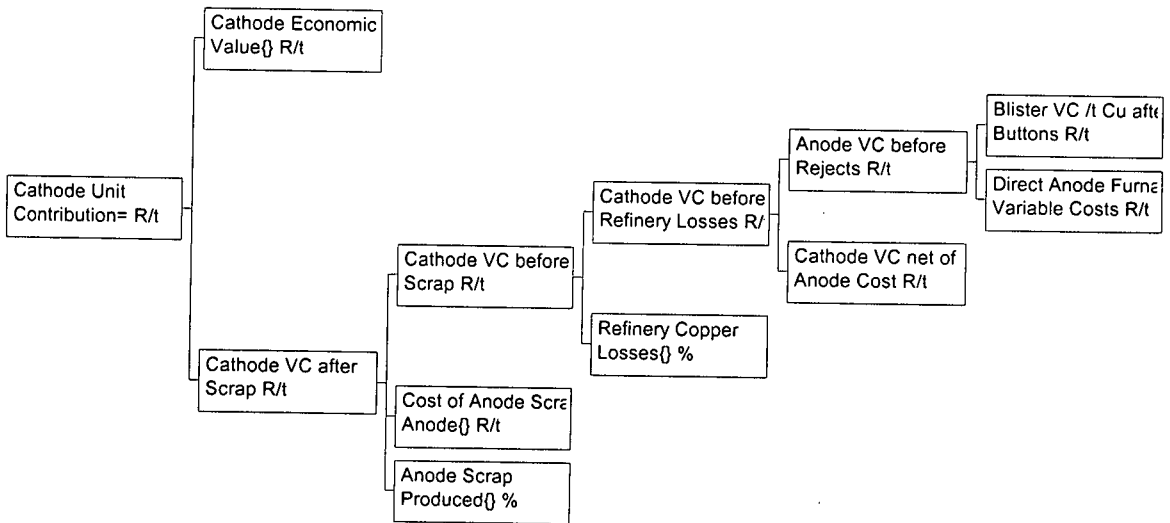


**Figure 5.2k (II). A portion of a "deep" view of the Cathode Unit Contribution (Palabora Focus Model, 1995)**

Firstly, it reflects the variable costs after the input feed from the previous step only, followed then by the next sub-section reflecting the recycling stream's variable cost contribution. This is followed by the views before and after the respective process's losses or recycle stream to its upstream neighbour.

This model structure design diagram of the smelter will further clarify this approach.
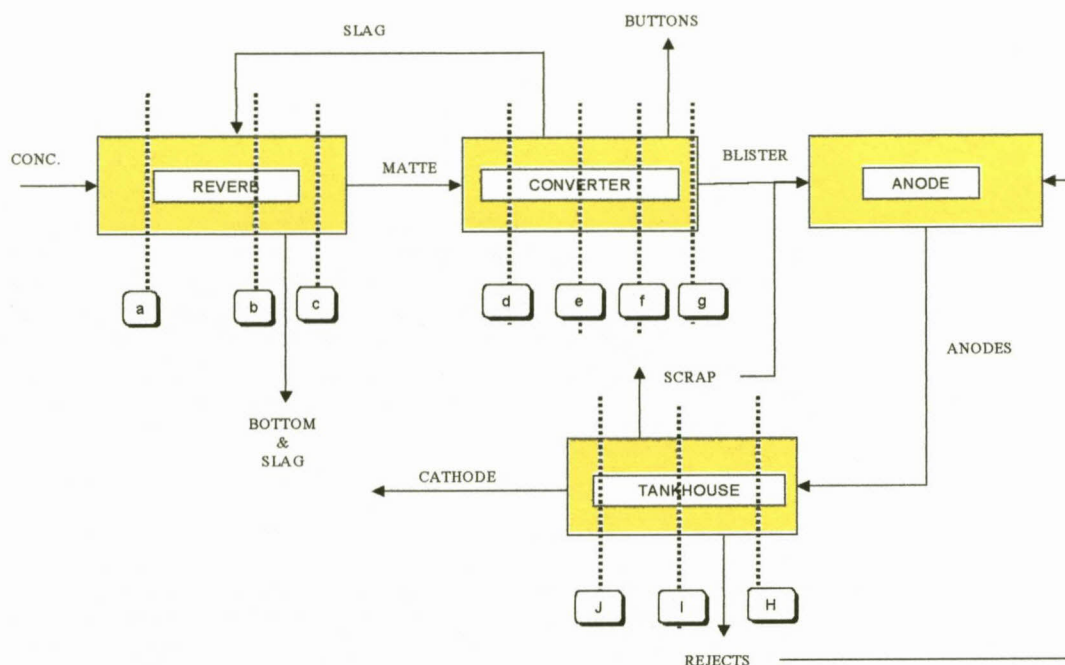


**Figure 5.2l. A plug-flow view of the Smelter and Refinery Value Chain (Palabora Focus Model, 1995)**

In this alternative view of the cathode production process chain, the cathode unit contribution (point J) is calculated as the economic value of the cathode less the variable cost after all costs have been considered, i.e. the cost of the scrap returned (point I), as well as the refinery losses through effluents (H) (each consideration is depicted by the dotted line and label in the diagram). Each of the costs is considered by a respective step in the nested structure; for example, as a step, take the final cathode variable cost, less the scrap to get cathode variable cost after scrap. The next step is to consider the cathode variable cost after scrap but before rejects, less the rejects to obtain to the cathode variable costs prior to considering the refinery rejects and scrap. Expressing the material flow in this way, alternative approaches to treating materials can be investigated to determine the optima.

Another branch of the smelter and refinery value-add structure formulates how the throughput is achieved. The higher levels are structured around the mass balance

logic, e.g. tons of cathode produced are determined from the anodes produced less the losses in the refinery and the scrap produced in the refinery.

As in the unit contribution branch, the steps are taken on at a time to the point where the chemical elements carried in by the minerals in the concentrate are used to derive a theoretical matte (unrefined copper metal) content. Starting from the chemical elements, since the mineralogical content analysis takes too long for operational decision-making, the theoretical expected slag and metal contents are calculated to offset this against the actual production as a benchmark.
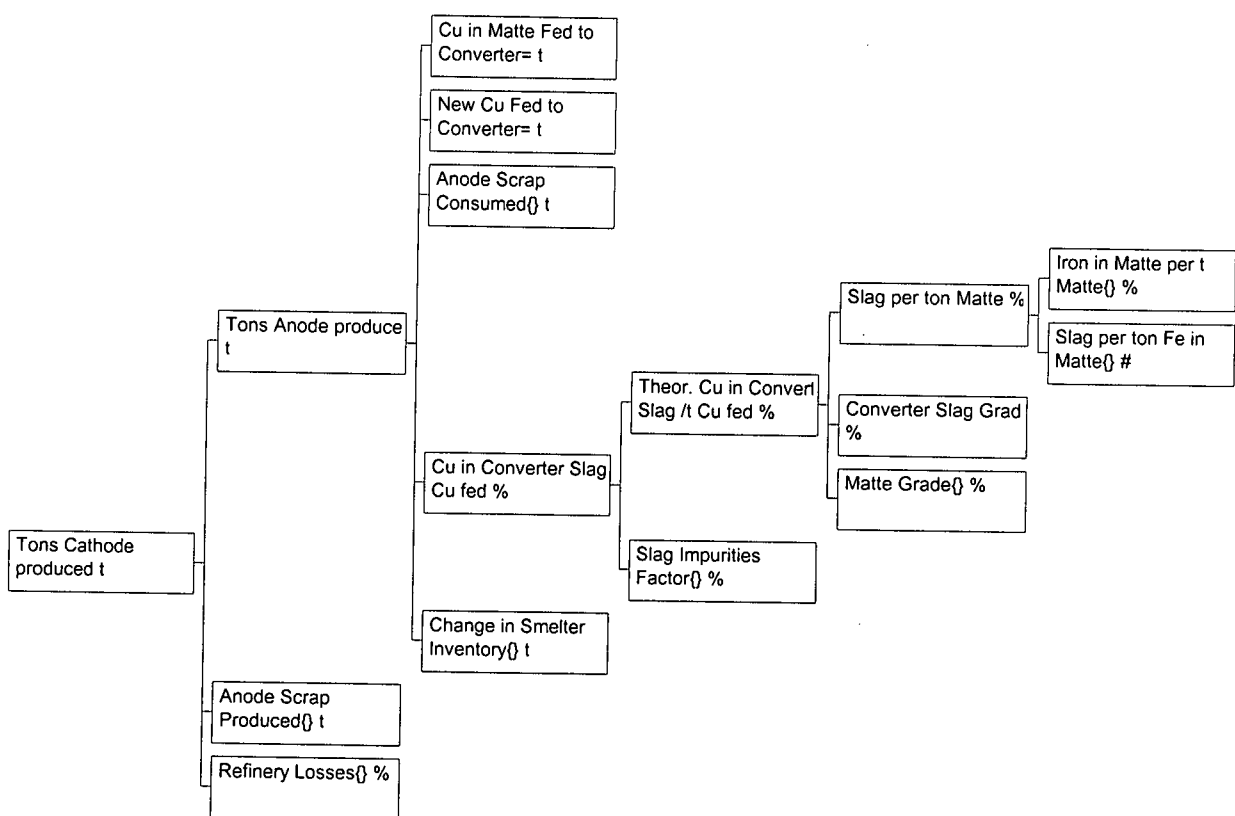


**Figure 5.2m. The Cathode Volume Tree (Palabora Focus Model, 1995)**
**( = after node description indicates an alternative branch)**

The converter part required a comparison of various approaches to understand the real performance drivers, and which constituted more of a constraint. Two parallel branches (marked with an = sign in the boxes of the figure 5.2m) were maintained.

The one continued the mass balance logic described above and the other subjected the throughput to the constraint by the air blowers on the converter and the matte grade.

To understand the logic behind the latter approach requires a glimpse at the science behind the process. The Peirce-Smith Converter technology (Biswas & Davenport, P12) is based on air that is blown through liquid copper metal to shift the iron component's equilibrium along the following stoichiometric processes:

For the FeS elimination or Slag formation step:

$$2FeS + 3O_2(air) + SiO_2(flux) \rightarrow 2FeO.SiO_2(slag) + 2SO_2$$
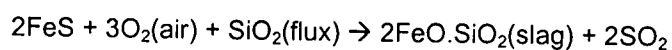
And the blister copper formation:

$$Cu_2S + O_2(air) + SiO_2(flux) \rightarrow 2Cu(*blister\ copper) + SO_2$$
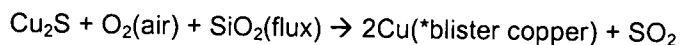
(*Blister copper, named after the fact that it forms blister-like shapes on cooling down, is the metal from the converter ready for fire refining)
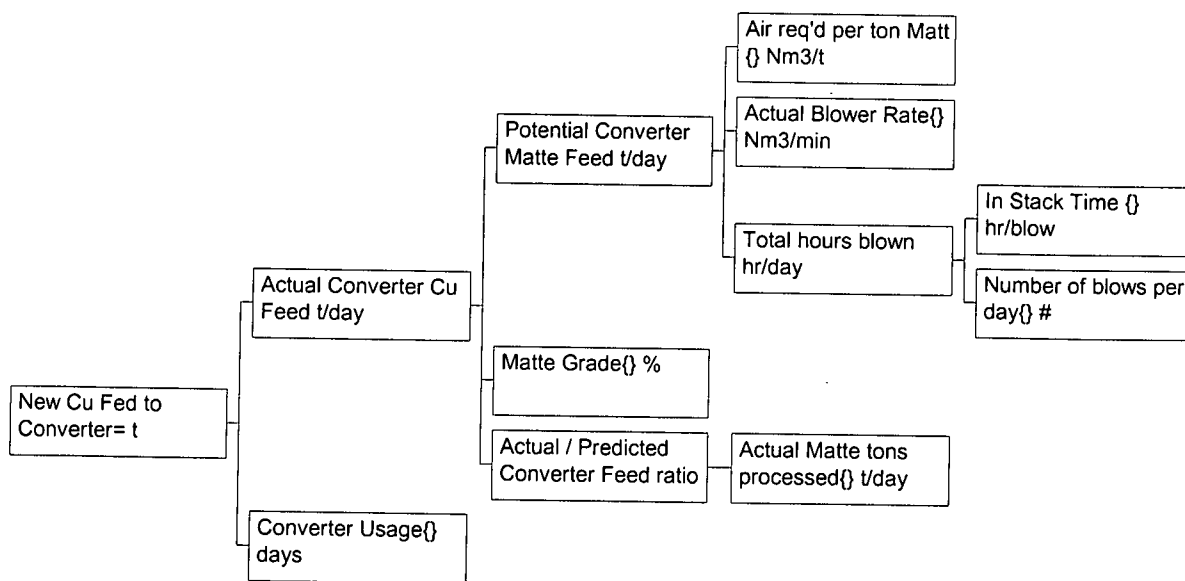


Figure 5.2n. The performance drivers of a Peirce-Smith Converter (Palabora Focus Model, 1995)

Assuming the matte grade is in the 39%-53%Cu range (Internal smelter reports, 1995), it is therefore logical that the more air available, the shorter the converter cycle times and hence, the higher the throughput. It goes without saying that this is a simplistic view and that other factors and limits are also relevant, e.g. that at blower rates higher than 700Nm$^3$/min, other secondary negative effects, such as losses of metal through the off-gas ducts, occur. With time, these refinements might be required, especially when the performance has changed so much that the new factors come into play. The actual calculations behind the model are derived from the following thinking drawn from a field study (Internal smelter reports, 1994):

**Table 5.2b. Assumptions used in Blower Rate Calculations**

| Determination of Air required in Converter | | |
|---|---|---|
| Assumptions | | |
| Blower rates | 800 | Nm$^3$/min |
| Matte grade % | 40 | %Cu |
| Magnetite in slag | 25 | %Fe$_3$O$_4$ |
| Silica in slag | 25 | %SiO$_2$ |
| Cu$_2$S in slag | 2.5 | %Cu$_2$S |
| Impurities in slag | 2.78 | % impurities |
| Matte tons per charge | 250 | ton matte |
| %Cu in slag | 2 | %Cu |
| Air density | 1.2929 | kg/m$^3$ |
| Oxygen in air | 23 | %O$_2$ |
| Slag Oxygen efficiency | 77 | % |
| Copper Oxygen efficiency | 77 | % |

Also note the following facts:

| Molecular weights | | |
|---|---:|---|
| Air | 29 | g/mole |
| Fe | 55.84 | |
| S | 32.06 | |
| Cu | 63.54 | |
| O | 15.999 | |
| Si | 28.08 | |
| $Cu_2S$ | 159.14 | |
| FeS | 87.9 | |
| FeO | 71.839 | |
| $SiO_2$ | 60.078 | |
| $Fe_3O_4$ | 231.516 | |
| $(FeO)_2.SiO_2$ | 203.756 | |

| Now: | | |
|---|---:|---|
| Air supplied through Blowers | 35714 | g.mole/min |
| times the mole weight of air = | 1036 | kg/min |
| | | |
| Given Matte = FeS + $Cu_2S$ | | |
| Then: | 250 | ton matte |
| contains | 100.0 | ton Cu |
| and | 125.2 | ton $Cu_2S$ |
| and | 124.8 | ton FeS |
| thus, giving us: | 79.3 | ton Fe |
| and: | 70.7 | ton S |
| | | |
| Consider the slag analysis: | | |
| FeO: | 44.72 | %FeO |
| Rest of elements in slag: | 55.28 | %rest |
| Then the Fe as $Fe_3O_4$ is: | 18.09 | ton / 100 t slag |
| and the Fe as FeO is: | 34.76 | ton / 100 t slag |
| The total Fe-bearing comp's in slag: | 52.85 | ton / 100 t slag |
| Expressed as % of total Fe-comp's: | 34.2 | %Fe in $Fe_3O_4$ of total comp's |
| | 65.8 | %Fe in FeO of total comp's |
| We know that the matte contains: | 79.3 | ton Fe |
| an that the slag contains: | 52.85 | ton / 100 t slag or %Fe |
| which is: | 150.0 | ton slag |
| | | |
| **Oxygen is consumed as follows:** | | |
| Slag Blow: | | |
| 1) FeS + 1.5$O_2$ -> FeO + $SO_2$ | | |
| 2) 3FeO + 0.5$O_2$ -> $Fe_3O_4$ | | |
| Copper Blow: | | |
| $Cu_2S$ + $O_2$ -> 2Cu + $SO_2$ | | |

From which follows:

| Slag blow air required: | | |
|---|---|---|
| **From 1 above):** | | |
| Every 1 ton of matte at a grade of: | 40 | %Cu |
| contains: | 499 | kg FeS |
| or alternatively: | 5.68 | kg.mole FeS |
| which is consuming 1.5xOxygen: | 8.52 | kg.moles of $O_2$ |
| | | |
| **From 2 above):** | | |
| Every 1 ton of matte contains: | 317 | kg Fe |
| of which a portion of: | 34.2 | % goes to $Fe_3O_4$ |
| which gives: | 108.5 | kg Fe |
| or alternatively: | 1.9 | kg.mole Fe |
| which consumes 0.5xOxygen: | 0.32 | kg.mole Oxygen |
| | | |
| **The total from 1) and 2) gives:** | 8.84 | kg.mole $O_2$/ton matte required |
| equals: | 283 | kg $O_2$/ton matte |
| or: | 1230 | kg Air /ton matte required |
| and at: | 77 | % efficiency |
| requires: | 1597 | kg Air /ton matte required |
| at a blowing rate of: | 1036 | kg/min |
| which is equivalent to: | 48 | x1000 $Nm^3$/hr |
| Thus: | 250 | ton matte |
| will require: | **386** | **minutes slag blow** |
| | | |
| **Copper blow air required:** | | |
| For every ton of matte: | 501 | kg of $Cu_2S$ |
| contains: | 101 | kg S |
| equals: | 3.1 | kg.mole S |
| which consumes: | 6.3 | kg.mole Oxygen |
| which is equivalent to: | 101 | kg Oxygen / ton matte |
| which is equivalent to: | 438 | kg Air / ton matte |
| Which, at an efficiency of: | 77 | % |
| requires air to the amount of: | 569 | kg Air / ton matte |
| at a blowing rate of: | 1036 | kg/min |
| which is equivalent to: | 48 | x1000 $N/m^3$/hr |
| Thus: | 250 | ton matte |
| will require: | **137** | **minutes copper blow** |
| | | |
| **Total Blowing time required is:** | **523** | **minutes** |

The actual converter production can therefore be calculated for the full range of possible matte grades, as well as the possible (air) blower rates:

**Table 5.2c. Converter production rates (Internal smelter reports, 1995)**

| *Production rate prediction based on matte grade and blower performance | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Air Req'd (kg / ton matte) | | | Air Req'd (Nm3 / ton matte) | | | Predicted production at Blower rates (Nm3/min) | | | | | | |
| MATTE GRADE | SLAG BLOW | COPPER BLOW | TOTAL BLOW | SLAG BLOW | COPPER BLOW | TOTAL BLOW | 650 | 675 | 700 | 725 | 750 | 775 | 800 |
| 38 | 1677 | 540 | 2218 | 1290 | 415 | 1705 | 22.9 | 23.7 | 24.6 | 25.5 | 26.4 | 27.3 | 28.1 |
| 39 | 1637 | 554 | 2192 | 1259 | 426 | 1686 | 23.1 | 24.0 | 24.9 | 25.8 | 26.7 | 27.6 | 28.5 |
| 40 | 1597 | 569 | 2166 | 1228 | 437 | 1666 | 23.4 | 24.3 | 25.2 | 26.1 | 27.0 | 27.9 | 28.8 |
| 41 | 1557 | 583 | 2140 | 1198 | 448 | 1646 | 23.7 | 24.6 | 25.5 | 26.4 | 27.3 | 28.3 | 29.2 |
| 42 | 1517 | 597 | 2114 | 1167 | 459 | 1626 | 24.0 | 24.9 | 25.8 | 26.8 | 27.7 | 28.6 | 29.5 |
| 43 | 1477 | 611 | 2088 | 1136 | 470 | 1606 | 24.3 | 25.2 | 26.2 | 27.1 | 28.0 | 29.0 | 29.9 |
| 44 | 1437 | 626 | 2063 | 1105 | 481 | 1586 | 24.6 | 25.5 | 26.5 | 27.4 | 28.4 | 29.3 | 30.3 |
| 45 | 1397 | 640 | 2037 | 1074 | 492 | 1566 | 24.9 | 25.9 | 26.8 | 27.8 | 28.7 | 29.7 | 30.6 |
| 46 | 1357 | 654 | 2011 | 1043 | 503 | 1546 | 25.2 | 26.2 | 27.2 | 28.1 | 29.1 | 30.1 | 31.0 |
| 47 | 1317 | 668 | 1985 | 1013 | 514 | 1526 | 25.5 | 26.5 | 27.5 | 28.5 | 29.5 | 30.5 | 31.4 |
| 48 | 1277 | 682 | 1959 | 982 | 525 | 1507 | 25.9 | 26.9 | 27.9 | 28.9 | 29.9 | 30.9 | 31.9 |
| 49 | 1237 | 697 | 1933 | 951 | 536 | 1487 | 26.2 | 27.2 | 28.3 | 29.3 | 30.3 | 31.3 | 32.3 |
| 50 | 1197 | 711 | 1907 | 920 | 547 | 1467 | 26.6 | 27.6 | 28.6 | 29.7 | 30.7 | 31.7 | 32.7 |
| * Normalised to 100 ton Cu | | | | | | | | | | | | | |

Another important observation is that where theoretical engineering design principles are used in the models, the predicted performances from its branch are usually offset against the actual performances. This provides a comparison of the actual and the theoretical performances, which might offer insights into what the real performance drivers are. For example, weak or no correlations between the predicted and actual converter throughput might indicate that the design principles are inadequate or that some measurements of the actual performances are in fact incorrect.

The alternative converter model that was evaluated hinges on the metallurgy in the reverberatory furnace as described by Biswas and Davenport (1980) that:

**Reverberatory furnace daily smelt rate = ((0.48 / % matte grade) ^ 0.5) x**
**(3.47 x Wet ton coal/day +**
**2.8 x Ton Oxygen consumed/day –**
**28 x % moisture in concentrate + 424)**

Figure 5.2o illustrates how this empirical structure is built into a model structure to maximise the ability to study the performance of the reverberatory furnace.
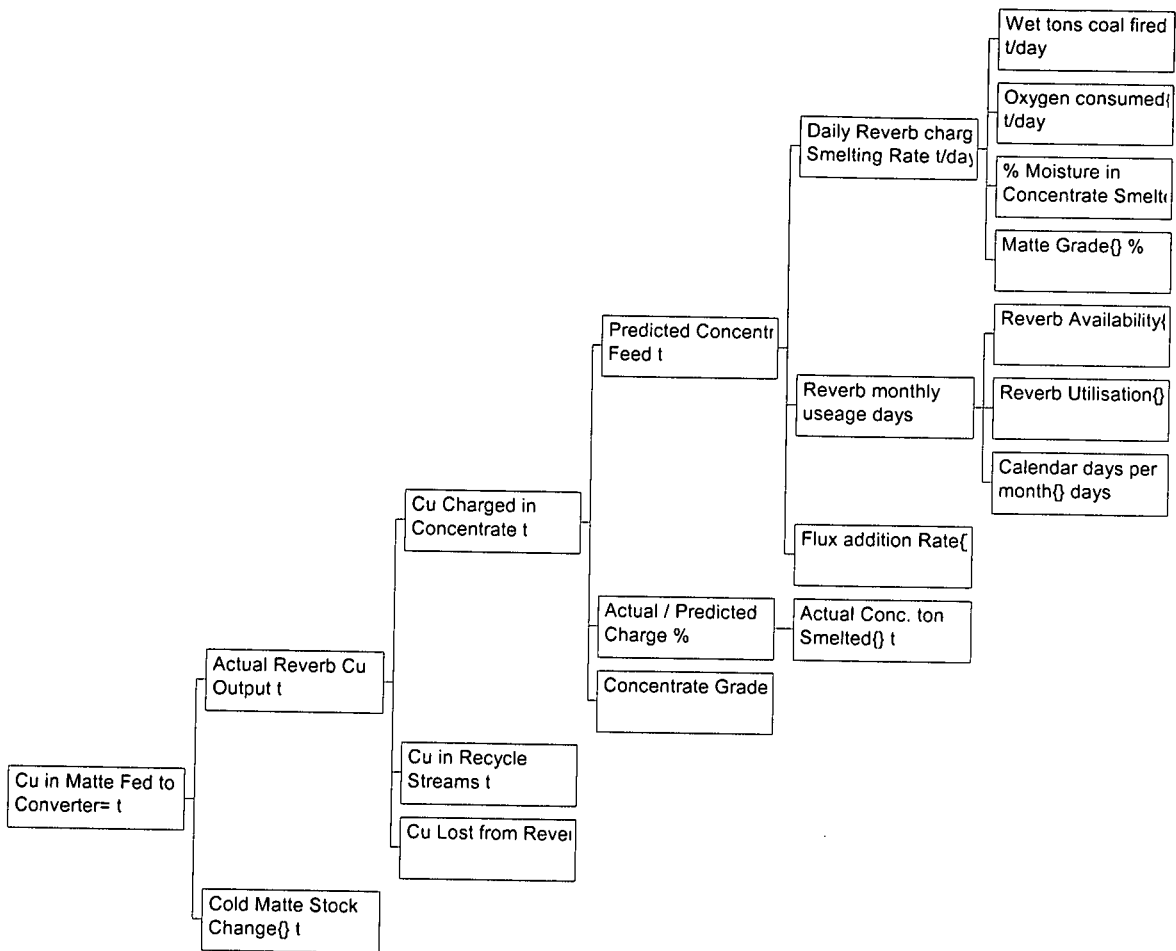
**Figure 5.2o. Drivers for the Reverberatory Furnace Smelter throughput (Palabora Focus Model, 1995)**

A further interesting minor branch is where the Cu losses through the converter slag are tracked. Here the volume slag is not measured and must be determined from basic principles.

## (v) Applications of the extended model:

The completed extended model may be used to do the following:

- **Study strategic alternatives** for exploiting the complete value chain.

- **Compare tactical alternatives** considering ALL economically and scientifically important drivers in a model that considers interrelationships.

- **Sources of Variances** and **Sources of Change assessments** may be made across the complete or subsets respectively.

- **Key profit drivers** can be determined and **continuous improvement projects** planned and monitored.

- **Trends** of certain outcomes may be studied by drilling down the structures into the trends of the drivers of the outcome.

- **Deriving <u>dynamic</u> "rules-of-thumb"** of the business that can easily be used for mental arithmetic. These ratios and norms are used throughout the industry but have a tendency to become constants that never change and are difficult to verify. The profit driver model resolves all these problems by making it possible to have a continuous update and verification of these norms and ratios.

- Some business issues can be studied and the **arguments tested** in issue maps for which again not only the structures but also the trends in the issue maps are connected and visible. The design principles ensure that a downward trend in, say, the economic value-adding of a section can be tracked down to a single branch (remember the mutually exclusive rule); it should be expected that the fundamental factor, and only the fundamental one, will show a clear downward trend that caused the value-add to drop.

The following sections will illustrate how the issue maps highlighted the best alternatives for various business issues.

## 5.2.2 Lessons learned from data collection, checking & syndication

The data search and collation process brought about valuable experiences regarding the information within an organisation. Most of the difficulties experienced could have been prevented if a complete enterprise management system has been installed. As this was not the case, the data collection became a long painful process. Specific lessons that deserve mentioned here are the following:

- A **highly fragmented information** system so typical of mines at the time was encountered. As such information had to be sourced from each department's own systems, mostly from spreadsheets.

- The fragmentation not only affected the departments along the value chain but also the **layers of reporting systems**. Three layers of reporting systems existed, each of which provided input to the generation of higher levels of management reports, each time requiring adjustments to be made. No audit trails of changes to data between the layers were kept. It was therefore not possible to "drill down" to the origins of the data to track the underlying causes.

- Each satellite data system had its own **formats**, summary rules and time periods which required the "translation" of these data sets into a format common to the corporate-wide system.

- The **culture** among the owners and users of the respective satellite systems had little interest in an external system's requirements. Hence, collating data sets for uploading into the model became quite an onerous task.

- The management teams found the new model exceptionally powerful and exciting. At the same time, they found the depth of the structures daunting and insisted on simple reports that looked like the reports they used every day.

It is clear that the tighter the model is integrated into the enterprise system the more it will be used. A separate, additional report to augment the existing reports is seldom if ever accepted especially if it has a longer term view to it – business pressures force one to adopt an extremely short term focus, with the latest crisis the centre of attention.

## 5.3 Performance Drivers Analysis

### 5.3.1 List of performance drivers

An abstract of the results of a variance analysis run on the model is shown in table 5.3a. Two sets of data based on the situation during June 1994 and December 1994, respectively, shows how dramatic relationships can change in such a short

space of time. The actual impact on the corporate bottom-line profits between the two periods is drastically reduced as well. The cathode economic (market) value and throughput have, for example, reduced to less than a quarter of what it was six months before. *This is testimony to the fact that "rules of thumb" derived in one month can be totally wrong for a next month and have to be updated regularly.*

**Table 5.3a. Abstract of the performance drivers (Palabora Focus Model, 1995)**

| No | Performance Driver Variance Analysis Description | Units | Jun'94 leverage | Dec '94 Leverage |
|---|---|---|---|---|
| 1 | Concentrate Economic Value | R/t | 3.64 | 1.41 |
| 2 | Mining and Milling Contribution | R'000 | 2.87 | 1.31 |
| 3 | Mining and Milling Unit Contribution | R/t | 2.87 | 1.3 |
| 4 | Mining and Milling Value-added | R'000 | 2.34 | 1.17 |
| 5 | Value of Cathode & by-Products | R/t | 4.69 | 1.05 |
| 6 | Long-Run Profit | Rm | 1 | 1 |
| 7 | Cathode Economic Value | R/t | 4.43 | 0.97 |
| 8 | Short-Run Profit | Rm | 1.03 | 0.95 |
| 9 | Effective FOR Price | R/t | 4.62 | 0.93 |
| 10 | Cathode Produced | R/t | 4.44 | 0.93 |
| 11 | Site Value-added | Rm | 2.57 | 0.83 |
| 12 | Net RCP-based FOR Price - Local | R/t | 3.22 | 0.62 |
| 13 | Taxes & Dividends | R'000 | -0.74 | 0.38 |
| 14 | % Volume - Local Cathode | % | 3.22 | 0.34 |
| 15 | Anode Scrap Produced | R/t | 0.89 | 0.25 |
| 17 | Actual Conc. ton Smelted | Ton | 1.01 | 0.22 |
| 23 | Site Overheads | R'000 | -0.37 | 0.17 |
| 26 | Marketing Value-added | Rm | 0.13 | 0.12 |
| 30 | Cu Charged in Concentrate | Ton | 1.01 | 0.09 |
| 32 | Actual Reverberatory furnace Cu Output | Ton | 1 | 0.08 |
| 36 | Stock Variation Copper | Rm | 0.18 | 0.08 |
| 37 | Cold Matte Produced | R/t | 0.16 | 0.07 |
| 38 | Operating Supplies Other | R/t ore | -0.03 | 0.07 |
| 39 | Actual Ore Grade | % | 2.87 | 0.06 |
| 40 | Cu in Matte Fed to Converter – View (i) | Ton | 0.95 | 0.06 |
| 41 | New Cu Fed to Converter – View (ii) | Ton | 0.95 | 0.06 |
| 42 | Actual Converter Cu Feed | t/day | 0.95 | 0.06 |
| 43 | Potential Converter Matte Feed | t/day | 0.95 | 0.06 |
| 52 | Tons Anode produced | Ton | 1.2 | 0.05 |
| 53 | Tons Cathode produced | Ton | 0.95 | 0.05 |

The reason for this dramatic change in the impact of the performance drivers on profit is due to considerable change in the market pricing conditions. This phenomenon and its impact on the industry will be discussed in the next section.

The performance drivers in this table cannot be called the **key** profit drivers yet. Although they have a marked impact on the bottom line, they do not necessarily have any improvement potential. What one needs to extract from this list are those drivers that have a strong bottom line impact **and** a high improvement potential. The process described in the project approach section was followed. To make more sense of the long list of drivers from which the above was extracted, the driver sets were compiled for discussion with the respective teams. In each case both the "normal" leverage and leverage under backwardation conditions was included for discussions.

## 5.3.2 Top performance drivers per value-chain component

Both performance drivers listed by teams and the drivers highlighted by the Focus® model (the ones with a leverage value behind it) were included to make for a complete picture. The three layers of drivers show the nested relationships between drivers. The different performance driver sets are tabulated to illustrate the outputs of each step, setting up the input into the subsequent steps in the KDP determination process.

**Table 5.3b. Mining performance drivers (Palabora Focus Model, 1995)**

| MINING: Levels of Key Performance Drivers | | | Leverage under B'ward'n | Normal Leverage |
|---|---|---|---|---|
| 1. Ore Mining Rate | | | 0.01 | 0.02 |
| | 1.1 Pit Geometry | | | |
| | 1.2 Capital Investment | | | |
| | 1.3 Equipment Availability | | | |
| | 1.4 Equipment Utilisation | | | |
| | 1.5 Stockpiling Costs | | | |
| | | 1.5.1 Loading Cost | 0 | 0 |
| | | 1.5.2 Hauling Cost | 0 | -0.15 |
| | 1.6 Waste:Ore ratio | | 0 | 0 |
| | 1.7 Blasting Size | | | |
| | | 1.7.1 Blasting Cost | -0.02 | -0.07 |
| | | 1.7.2 Mill Rate change | 0 | 0.02 |
| 2. Total Fixed Costs | | | 0.11 | |
| | 2.1 Mine Life | | 0.01 | -0.03 |
| | 2.2 Labour Complement | | | |

The fixed cost component for mining stands out – the results of the leverage calculation imply that a 1% change in the fixed costs will change the bottom line profit by 0.11%. Also notice that the shorter the mine life the higher the profit, confirming that fewer cost periods will result in positive savings.

**Table 5.3c. Milling performance drivers (Palabora Focus Model, 1995)**

| MILLING: Levels of Key Performance Drivers | | | Leverage under B'ward'n | Normal Leverage |
|---|---|---|---|---|
| 1. Milling Rate | | | | |
| | 1.1 Conv. Milling Rate | 1.1.1 % Dolerite | 0 | |
| | | 1.1.2 Feed Size | | |
| | 1.2 Auto Milling Rate | 1.2.1 % Dolerite | 0 | |
| | | 1.2.2 Feed Size | | |
| | 1.3 Equipment Avail | | | -0.02 |
| | 1.4 Equipment Utilis'n | | | |
| 2. Mineralogy | | | | |
| | 2.1 % Copper minerals | | | |
| | 2.2 % Dolerite | | 0 | |
| | 2.3 % Gangue | | | |
| 3. Recovery | | | -0.04 | 2.87 |
| | 3.1 Particle Size | | | |
| | | 3.1.1 Mill Retention time | | |
| | 3.2 Float Res. Time | | | |
| | 3.3 Conc. Grade | | -0.05 | 1.01 |
| | 3.4 Copper minerals | | | |
| | 3.5 Reagent dosage | | | |
| | 3.6 Economics | | | |
| | | 3.6.1 Thru'put: Rec - curve | | |
| | | 3.6.2 Smelting Costs | 0.01 | -0.09 |
| | | 3.6.3 Tails Copper Value | | |
| | | 3.6.4 Fixed Costs Savings | | |
| 4. Mill Variable Costs | | | | |
| | 4.1 Grinding Media | | -0.05 | -0.05 |
| | 4.2 Flotation Reagents | | -0.04 | -0.04 |
| 5. By Product Contr. | | | -0.02 | 0.25 |
| | 5.1 Heavy Minerals | | -0.05 | 0 |
| | 5.2 Zirconia | | 0.03 | 0.23 |

Under normal market pricing conditions, the recovery and consequently, concentrate grade shows the highest impact in the milling driver set.

**Table 5.3d. Smelter performance drivers (Palabora Focus Model, 1995)**

| SMELTER: Levels of Key Performance Drivers | | | Leverage under B'ward'n | Normal Leverage |
|---|---|---|---|---|
| 1. Smelting Rate | | | | |
| | 1.1 Heating Capacity | | | |
| | | 1.1.1 Oxygen consumed | 0 | -0.01 |
| | | 1.1.2 Coal consumed | 0 | -0.04 |
| | 1.2 Moisture content | | -0.01 | -0.21 |
| | 1.3 t Cu/ t Cold feed | | 0 | 0.09 |
| | | 1.3.1 Concentrate grade | 0 | 0.09 |
| | 1.4 Availability | | 0 | 1.08 |
| | 1.5 Utilisation | | 0 | 1.08 |
| 2. Flux addition rate | | | 0.01 | -0.07 |
| 3. Copper losses | | | -0.01 | -0.04 |
| | 3.1 Bottom Losses | | -0.01 | -0.02 |
| | | 3.1.1 Bottom lost tons | 0 | -0.02 |
| | | 3.1.2 Bottom Grade | -0.01 | -0.02 |
| 4. Stock changes | | | -0.01 | -0.05 |
| 5. Smelting Fixed costs | | | -0.12 | -0.23 |
| 6. Acid fixed costs | | | -0.03 | -0.05 |
| 7. Reverberatory furnace var. costs | | | 0.01 | -0.09 |
| | | | | |
| 1. Cu tons to Converter | | | 0.06 | 0.95 |
| 2. Matte grade | | | 0 | 0.95 |
| 3. Hours blown | | | 0.12 | |
| | 3.1 Availability | | | |
| | 3.2 Utilisation | | | |
| 4. IST | | | 0.04 | 0.95 |
| 5. # blows/day | | | 0.02 | 0.95 |
| 6. Scrap consumed | | | -0.01 | 0.24 |
| 7. Conv. Variable costs | | | -0.01 | -0.06 |
| 8. Refractories | | | -0.01 | -0.02 |
| | | | | |
| 1. Anodes produced | | | 0.05 | 1.2 |
| | 1.1 Availability | | | |
| | 1.2 Utilisation | | | |
| 2. Anode Furn. var. cost. | | | 0 | -0.02 |

The throughput of the reverberatory furnace, as well as the converter and anode furnaces, is most important under normal conditions. The converter performance factors are quite prominent in driving profit under these circumstances. The improvement projects reflect these facts as they aim to address these drivers.

**Table 5.3e. The Refinery performance drivers** (Palabora Focus Model, 1995)

| REFINERY: Levels of Key Performance Drivers | | | Leverage under B'ward'n | Normal Leverage |
|---|---|---|---|---|
| 1. Cathode Produced | | | 0.05 | 0.95 |
| | 1.1 Tankhouse utilis'n | | | |
| | 1.2 Pull Weight | | | |
| | | 1.2.1 Current Efficiency | | |
| | | 1.2.2 Shorts | | |
| | | 1.2.3 Power-on-time | | |
| | 1.3 Anode Scrap Prod. | | 0.01 | -0.24 |
| 2. Refinery Losses | | | | |
| | 2.1 Inv. Control | | | |
| | 2.2 Effluent control | | | |
| | 2.3 Tankloading pract's | | | |
| 3. Refinery Fixed Costs | | | -0.01 | -0.08 |
| | 3.1 Labour | | | |
| 4. Coal consumption | | | 0 | -0.03 |
| 5. Anode Slimes Contrib. | | | -0.01 | 0.18 |
| | 5.1 Anode Slimes Price | | 0.01 | 0.18 |
| | 5.2 Anode Slimes prod. | | -0.02 | 0.18 |
| | | 5.2.1 Effluent control | | |
| | | 5.2.2 Tankloading pract's | | |
| | | 5.2.3 Circulation pract's | | |

Apart from the throughput in the refinery, the amount of scrap produced shows a pronounced negative impact on the profits of the company.

Clearly the FOR (Free On Rail) price dominates the impact on the profit for rod and to a lesser extent, the impact on the concentrate sales.

Discussions with the respective teams led to the definition of the cash cost impact of each of the initiatives, which resulted in turn into a series of improvement projects.

Lastly, the sales and marketing component of the value chain:

**Table 5.3f. The Sales and Marketing performance drivers  (Palabora Focus Model, 1995)**

| SALES AND MARKETING: Levels of Key Performance Drivers | | | Leverage under B'ward'n | Normal Leverage |
|---|---|---|---|---|
| 1. Rod Value-added | | | 0.02 | 0.02 |
| | 1.1 Rod Production | | 0.01 | 0.06 |
| | 1.2 Conversion charge | | 0.01 | 0.07 |
| | | 1.2.1 7.9mm | 0 | 0.06 |
| | | 1.2.2 6.35mm | 0 | 0 |
| | 1.3 TCRC supplies | | 0 | -0.01 |
| | 1.4 Fixed Costs | | 0 | -0.01 |
| | 1.5 ASARCO costs | | 0 | -0.03 |
| 2. Cathode Value-added | | | 0.05 | 0.06 |
| | 2.1 Effective FOR Price | | 0.93 | 4.62 |
| | | 2.1.1 RCP - Local sales | 0.62 | 3.22 |
| | | 2.1.2 NDA | 0.16 | 0.54 |
| | | 2.1.3 Nissho | 0.08 | 0.32 |
| | | 2.1.4 BICC | 0.06 | 0.3 |
| | | 2.1.5 Excess | 0.01 | 0.24 |
| | | 2.1.6 Copper Price | -0.91 | -4.66 |
| | | 2.1.7 Export Transport | 0.02 | 0.2 |
| | 2.2 Volume Sold | | 0 | 0.06 |
| 3. Concentrate Sold | | | -0.01 | 0.05 |
| | 3.1 Effective FOR Price | | 0.11 | 0.27 |
| | | 3.1.1 Copper Price | -0.06 | -0.3 |
| | | 3.1.2 TCRC costs | -0.02 | 0.05 |
| | | 3.1.3 Transport costs | 0.02 | 0.02 |
| | | 3.1.5 Payables Contr. | 0 | 0.01 |
| | 3.2 Volume Sold | | -0.01 | 0.05 |

(B'ward'n = Backwardation)

## 5.3.3  Determining the impact of bottom line

The smelter will be used as an example of how the leverage calculation outputs looked like. After discussing the above performance drivers, the key initiatives for the smelter were identified and the cash cost impact determined. The initiatives are tabulated in table 5.3g:

**Table 5.3g. Profit improvement initiatives for the Smelter (Palabora Focus Model, 1995)**

| Project Description | Increase in Conc. Smelting Rate for 1995 (tpd) | Increase in production per annum (tons) 34,4%Cu in Copper | | Probability | | Capital Cost | Pre-Tax Profit Impact |
|---|---|---|---|---|---|---|---|
| | | Concentrate | Copper | Factor | Adjusted Copper | (R'000) | (Rm) |
| Pre-heat Secondary air | 5 | 1700 | 570 | 1 | 570 | 1000 | 1.96 |
| Melting Furnace | 0 | 7300 | 2450 | 0.9 | 2205 | 3000 | 1.87 |
| Utilising 4th Pulveriser | 8 | 5500 | 1840 | 1 | 1840 | 500 | 1.56 |
| Tuyere Punching & Drilling | 4.2 | 2900 | 970 | 1 | 970 | 680 | 0.82 |
| Matte Grade stabilisation | 0 | 3500 | 1170 | 0.8 | 936 | 2000 | 0.80 |
| Acid Plant Availability | 4.4 | 3100 | 1040 | 0.8 | 832 | 6000 | 0.71 |
| Boiler Bypass | 0 | 3600 | 1210 | 0.5 | 605 | 3250 | 0.51 |
| Day Bins | 1.3 | 1800 | 600 | 1 | 600 | 600 | 0.51 |
| Blister casting | 1.5 | 1000 | 340 | 1 | 340 | 200 | 0.29 |
| Pilaster | 0 | 1000 | 340 | 0.8 | 272 | 500 | 0.23 |
| **TOTAL** | **24** | **31400** | **10530** | | **9170** | **17730** | |

The profit impact is calculated from the %leverage and the %improvement potential as described in the project approach section. Having identified the key profit drivers, the real star drivers will show up and can be presented in the format described in the project approach section. The final graph looks as follows:
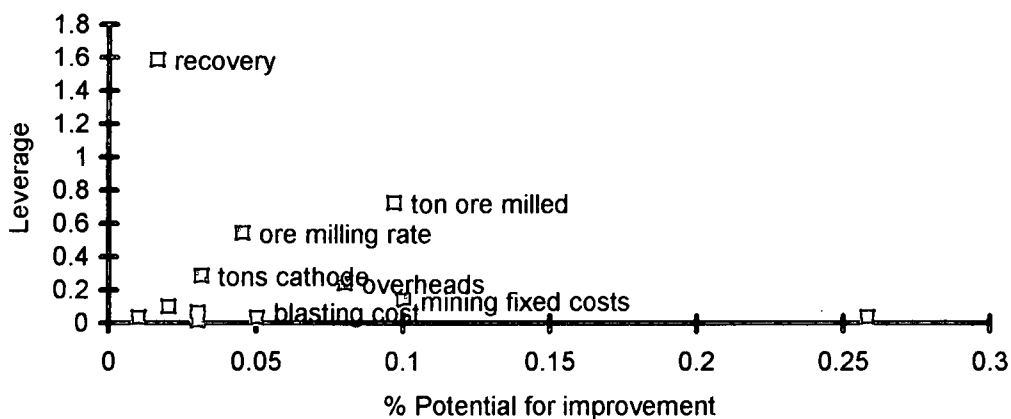


**Figure 5.3a. The Leverage Diagram with performance drivers (Palabora Focus Model, 1995)**

Even these key profit drivers show a similar business-as-usual pattern with the driver points lying close to the axes. The variables "tons ore milled", "mining fixed costs", "ore milling rate", and "overheads" stand out as key focal points.

One other way of representing the impact of the variables on corporate profits is what has been labeled "Waterfall diagrams" due to their resemblance of a waterfall. They aim at ranking the drivers by impact.
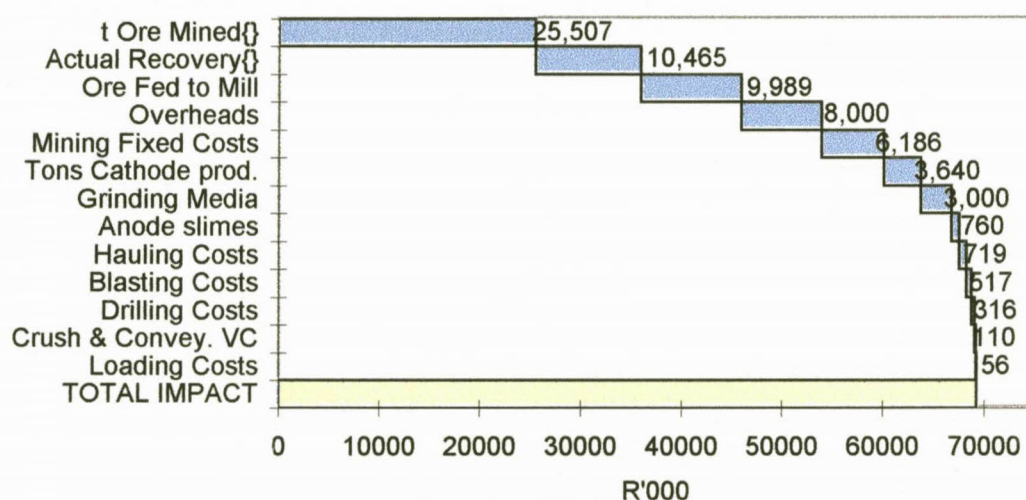


**Figure 5.3b. The waterfall diagram with key initiatives (Palabora Focus Model, 1995)**

At this point no confusion should exist in the organisation as to where the organisation should focus to maximize the corporate profits. The business model should play a pivotal role as monitoring and forecasting management tool.

### 5.3.4 Defining some rules-of-thumb

An interesting derivative from the Focus® model is the set of parameters that are used in day-to-day mental arithmetic. It embodies the broader thinking that the programme seeks to stimulate in the organisation. An extract of this "rule-of-thumb" table looks as follows:

**(Figures quoted here are taken over an 18-month period: June '93 to Dec '94.)**

1. **Total Fixed Costs: R240m - R300m p.a.**
   Included are the following elements:
   - Operating & Maintenance Labour
   - Extra-ordinary Costs
   - Indirect Costs (Technical, Human Resources, Management, Environmental)
   - Non-operating Costs (Service Fee RTZ, Management Costs - RTMS, Corporate & Non-mine)

2. **Fixed Cost Breakdown**
   - Mining: .................. R5m - R6m p.m. (R2.0/t ore)     => R900/t Cu (18%)
   - Milling: ...................R5m p.m.     (R2.0/t ore)     => R900/t Cu (18%)
   - Smelting: ...............R3.5m p.m.   (R1.4/t ore)     => R630/t Cu (12,6%)
   - Refining: ................R1.5m p.m.   (R0.6/t ore)     => R270/t Cu (5,4%)
   - Indirect Costs: ........R5m p.m.     (R2.0/t ore)     => R900/t Cu (18%)
   - Non-operating: .......R2m p.m.     (R0.8/t ore)
   - **Monthly total: ........R20m - R25m (R9.8/t ore)**

3. **Mining & Milling Unit Contribution:   R6000 - R8000/t Cu**
   - Mining & Milling Unit Variable Costs:..R1000/ t Cu     => R1000/t Cu (20%)
   - Concentrate Economic Value: ...........R5000/t Cu - R9000/t Cu
   - Milling Unit variable costs: .................R2/t ore
   - Pit variable costs: ..............................R3 - R4/t ore
   - Pre-crushing variable costs: ...............R1.5 - R1/t ore

4. **Smelting & Refining Unit Contribution:   R1000/t Cu**
   - Cathode Economic Value .........R6000/t Cu - R10000/t Cu
   - Cathode Unit Contribution ........R500 - R750/t Cu
   - Payables Unit Contribution .......R300/t - R450/t Cu
   - Refining or Cathode Unit V.C. ..R75/t Cu - R80/t Cu   => R  80/t Cu (1.6%)
   - Anode Furnace V.C. .................R30/t Cu - R40/t Cu   => R  40/t Cu (0.8%)
   - Converter V.C. ..........................R75/t Cu            => R  80/t Cu (1.6%)
   - Reverberatory furnace V.C. .............................R150/t Cu - R250/t Cu      => R 200/t Cu (4%)

   ON SITE COSTS:      R5000/t Cu

5. **Backwardation**

   - Sell concentrate when backwardation is larger than Smelting & Refining unit contribution (R800/t Cu - R1200/t Cu)
   - Backwardation levels: (Cash price - 27 months forward contract price)

| Month | USD/ton | Rand/ton | Month | USD/ton | Rand/ton |
|-------|---------|----------|-------|---------|----------|
| Jun '94 | 85 | 307 | Jan '95 | 676 | 2384 |
| Aug '94 | 179 | 645 | Mar '95 | 391 | 1400 |
| Oct '94 | 140 | 494 | May '95 | 368 | 1344 |
| Dec '94 | 716 | 2541 | July '95 | 501 | 1824 |

Using these rules-of-thumb, one begins to appreciate certain interesting ratios. For example, half of all fixed costs are accrued to produce the first saleable product, namely, copper concentrate; and that the concentrate unit contribution is only R1000/t Cu less than the final product for which one has to spend another third of the total fixed costs. One recognises the relatively high fixed cost for the mine alone, which becomes an important fact for the issue around the life of mine discussed in the next section. A further interesting fact is that the contribution from the metals within the byproducts is remarkably high, and hence might offer profit potential.

The logic behind point 5, relating to the alternatives available to the company under backwardation situation, will be discussed under the evaluation of the business issues in the next section.

## 5.4 Evaluation of Issues

A number of the business issues listed during the modelling process deserve specific discussion since it became evident that through the business modelling process, the economic framework for resolving the issues was put in place. It was already clear early in the project that taking a fresh view of the business and challenging traditional thinking was necessary before the change could be brought about.

### 5.4.1 A new economic view of the business

Considering the given fact that the open pit was at its end of mine life and the prospects for an underground mine looked marginal, if at all, then resources could be considered to be limited. Shareholders would like to see the maximum value to

be extracted from the remainder of the resources without losing track of the possibility of an underground mine.

The question that the above raises with the management team is what the real wealth performance drivers under these circumstances would be. The study has indicated that the fixed cost component is high with relation to other industries, even when considering personnel costs as variable, i.e. varying directly with fluctuations in throughput volumes (which it is not). To add to the prominence of fixed costs is that variable costs have been a constant area of focus, which is where the focus should be under normal conditions anyway. One could therefore expect some savings potential within fixed costs when approaching end of mine life.

The question to be asked here is how corporate profits are calculated under conditions of <u>infinite</u> resources and to which extent this applies to the finite resource situation? The simplistic view (Sylvester, 1995) of the calculation is:

$$\pi_s = (SP - C_v) \times V - C_f$$

where:

$\pi_s$ = Short-term profit, calculated over the period of an accounting year

SP = Unit sales price

$C_v$ = Unit variable cost

V = Volume (tons)

$C_f$ = Fixed costs

And:

$(SP - C_v) \times V$ = is the Unit contribution x Units Produced, a term that is variable whilst $C_f$ is fixed for the respective period, usually the reporting year.

However:

Under <u>finite</u> resource conditions and wanting to establish the total remaining profit to be forthcoming from the ore reserve, a number of safe assumptions can be made.

- Due to the short time period remaining, one can assume an average metal price and a standard unit extraction cost, which yield an average unit

contribution. From the discussion under section 3, it is evident that both the sales price and variable costs are assumed to be rising at an average risk-free rate. The difference between the two gives a <u>constant</u> margin.

- Instead of taking the reporting year view, the remainder of lifetime is considered and therefore the remainder of the reserve as production volume. This remainder is a fixed amount $V_{rem}$.

$$\pi_L = (SP - C_v) \times V_{rem} - C_p \times V_{rem} / V$$

where:

$\pi_L$     = <u>Long</u>-term profit, i.e. calculated over the remainder of the life of mine

$V$     = the <u>variable</u> volume produced per period

$V_{rem}$     = The total remaining volume (tons) of product in the ore reserve

$V_{rem} / V$ = The number of periods required to turn the remainder of the ore reserve into product. The number of periods will vary with V.

$SP$     = Average or fixed unit sales price

$C_v$     = Average or standard unit variable cost

$C_p$     = Fixed costs per period or Period Costs. Thus, the fixed cost to continue for an additional period. It is the same as $C_f$.

And now:

- $(SP - C_v) \times V_{rem}$ = an average or <u>fixed</u> unit contribution x a fixed volume ore, therefore a fixed, known expense for the remainder of the reserve.

- $C_p \times V_{rem}/V$ = a variable amount of total period costs depending on the annual mining rate (V)

This alternative view suggests that the key profit driver will be the annual mining rate as it will determine the number of periods and hence the total fixed cost bill. The long-term profit, $\pi_L$, differs from the short-term profit, $\pi_S$, in that it will vary with fluctuations in V which will vary the number of periods. In business modelling both

the short-term and long-term views are kept, the latter showing the profit after an adjustment to the short-term view.

The actual impact is illustrated in Table 5.4a:

**Table 5.4a. Short-term vs. long-term effects of a throughput increase (Palabora Focus Model, 1995)**

|  | Short-term Profit | Long-term Profit | Production per annum | $(SP-C_v)$ | $C_f$ |
|---|---|---|---|---|---|
| Base Case | R12m | R12m | 1.6Mt | | |
| Actual due to increased throughput | 12+(2-1.6)*8 = R15.2m  (Note: Sales brought forward) | 12+0.25*4 = R13m  (note: (2-1.6)/2 i.e. save 1 Qtr) | ⬅ 2Mt | R8/t | R4m |
| %Change | 27% | 8% | | | |

Note: Backwardation not considered here

Assume a base case of 1.6Mt production resulting in a profit of R12m. A step-change in the production rate of 400kt to 2Mt p.a. will reflect differently in the two views. With the short-term view, the additional production will bring in an additional R3.2m for the year. The long-term view would consider the R3.2 as mere sales brought forward (with only interest earned for earlier sales) and discounts it altogether as any increase in overall wealth generation. It does consider the reduction of fixed cost periods by 0.25 year as a period cost saving of R1m (R4m fixed cost p.a. x 0.25 year reduced). The short-term view will appear under the traditional annual reporting view as a 27% improvement in performance, whilst in the long-term view (which is the investor's view) the improvement is a mere 8%.

The long-term adjustment therefore modifies the overstated performance improvement down to the shareholder view as shown in figure 5.4a:
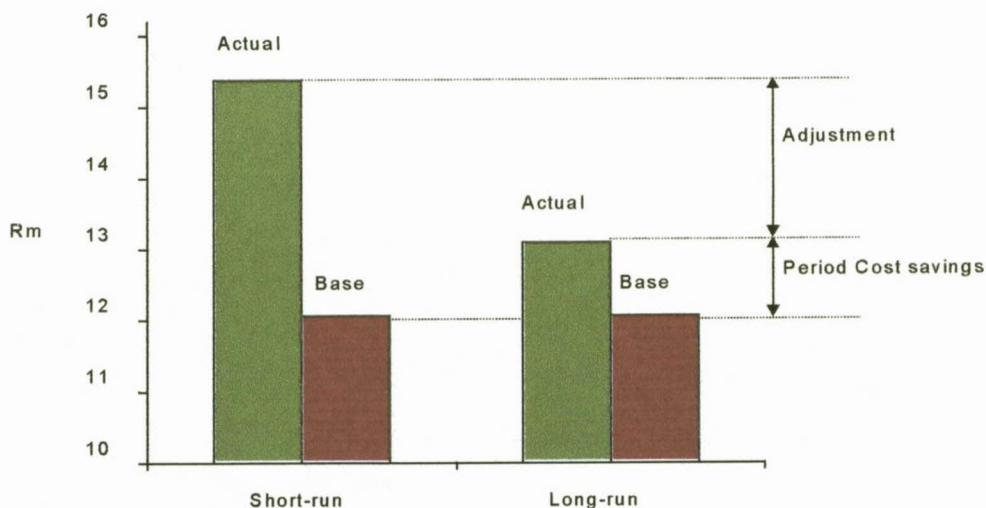
Note: Assumes no backwardation

**Figure 5.4a. Long-run over short-run adjustments (Palabora Focus Model, 1995)**

These views also impact on the decisions about the operating constraints that will be discussed in section 5.4.3.

The following section covers the market metal pricing situation. To simplify the arguments laid out here, the backwardation situation uncovered during the project is excluded in the ensuing discussion.

## 5.4.2 Copper market pricing conditions

In figure 5.4b, the world Copper inventory is plotted against three different prices, namely, the current cash price, the three-month and twenty-seven month future prices, respectively. These forward prices are particularly important for put or call transactions and reflect the market's forecast of what the supply-demand situation is going to be. Refer to section 3 for the background on *backwardation* and *contango* market price situations.

Figure 5.4b shows how, from around April 1994, the copper price drifted from its inverse relationship with the world copper inventories. No longer did the price go up

as the copper stocks were consumed. The current price and the future prices started drifting apart.

How can a mine exploit this market condition to maximise its profits? And what is the impact on the mine's long term wealth? What are the key factors that impact on decision making in a situation like this?
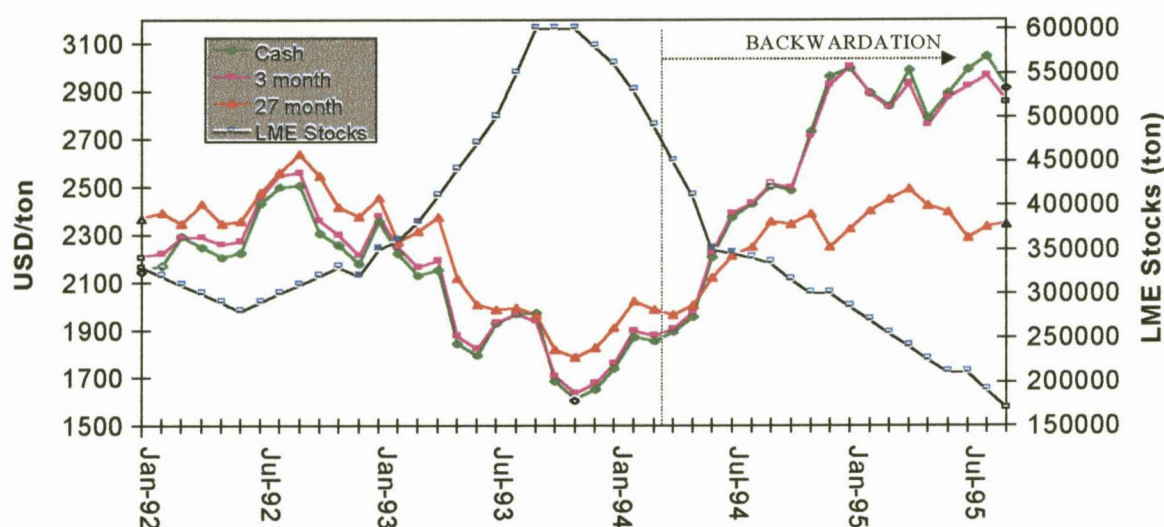


**Figure 5.4b. Cash and future prices vs. LME stock levels (Palabora Focus Model, 1995)**

Twenty-seven month future prices also move sideways at a lower level since the future prices are bound to be lower than the demand-supply balance return to normal. What is of particular importance to the producer is that a sale today is a definite bargain in terms of the next 27 months' metal pricing.

Consider the following example: Turning attention back to the internal value chain as illustrated in an earlier section. There is a clear separation in the internal value chain around the concentrate stockpiles in front of the smelting section. Should one sell the concentrate at the current inflated price and lose the downstream value-adding opportunity? If so, what will be the net result and which factors does one consider in the process?

Consider the following diagram:
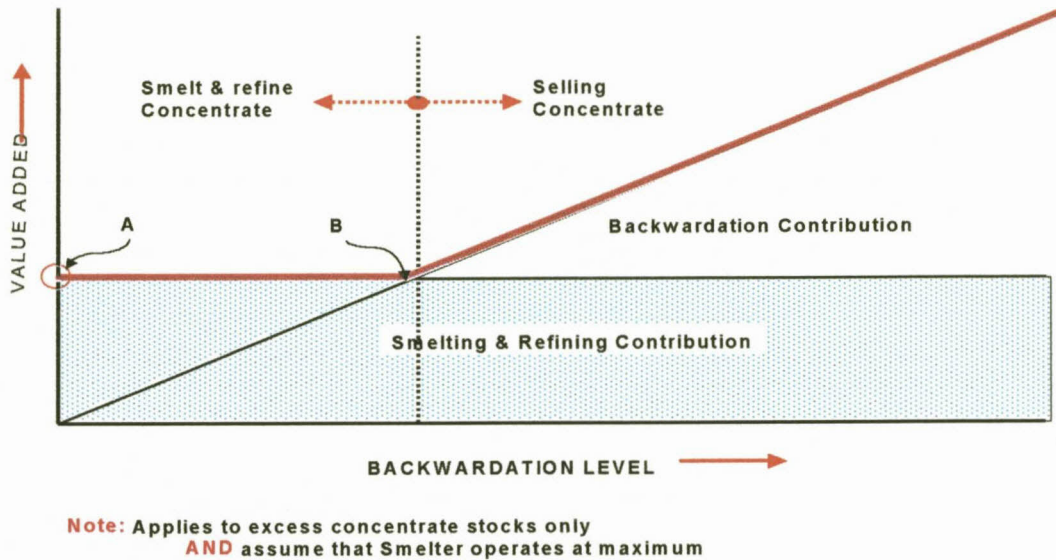


**Figure 5.4c. The breakeven of backwardation and value-added by the smelter (Palabora Focus Model, 1995)**

Moving along the y-axis, one notices that the smelting and refining process adds value (about R500/t Cu in 1995) to the concentrate up to point A on the value-add dimension. In order to maintain an acceptable level of return on assets, converting concentrate into cathode will always be the preferred route for maximising returns.

If, however, (i) the smelter is running at its maximum throughput and (ii) excess concentrates still continue to be produced, and (iii) the stockpiles are far beyond the safety stock limits so that the concentrate will only be processed two years hence. And if, of course, (iv) backwardation exists at a level in excess of the value that the preferred route can add, i.e. point B and beyond, then a decision should be made whether to sell concentrates or keep producing cathode from it. It is only the level beyond B where it shows a higher contribution and should the concentrate-selling route be considered.

Should the concentrate production then continue when the stockpiles in front of the smelter is that high? If backwardation conditions are not conducive to the

concentrate-selling route, the long-term economic view might still require that the mining and milling sections should continue to overproduce due to the potential period cost savings. This argument is, however, not that simple, as various other drivers come into play, as the next section will uncover.

### 5.4.3 Understanding the bottlenecks

Goldratt (1990: 53) expands on the saying that the strength of a chain is determined by the weakest link when he asks: "how many weak links exist in a company?" He continues to answer the question: "that depends on how many chains exist. It cannot be too many". Underpinning his logic is the view of what is the single, most important constraint. Whilst this appears to be plausible, it does not help teams to understand the difference in nature of the constraints they might experience.

What do we mean by difference in nature of constraints? If one reflects on the long- and short-term views, it becomes clear that whereas shareholders want wealth over the life of mine to be maximised, middle management wants to achieve short-term targets. It is conceivable then that these two groups might perceive different constraints which might not be conflicting perceptions at all. The short-term constraint(s) must indeed be understood in terms of the longer-term constraint(s).

Three kinds of constraints were identified during the study, namely:

- The <u>savings</u> bottleneck at Mining

- The <u>wealth</u> bottleneck at Milling

- The <u>profit</u> bottleneck at Smelting

Each definition of a bottleneck visualises the essence of the constraint to help the respective teams to understand what they entail and what to do to help achieve the key goals and objectives of the company. Let us consider these constraints individually below:

## (i) Mining: The savings bottleneck

Two important facts came to light namely, that at the time of the study the mine was running at a mining rate to keep the concentrator at maximum throughput rate. As soon as the fine ore stockpiles are full the mine stops some activities and engage in preventative maintenance. This would have continued to a point where the pit geometry would begin to impede the mining rate, which was not yet the case.

Secondly, having to consider what the impact of an underground mine would be on these views of the business, it turned out that an open pit and a block cave mine can be operated simultaneously for a period of up to five years, with an allowed planning overlap of three years. This made it conceivable to bring forward the underground mining activity in a way that smoothes the transition period also in terms of wealth creation, as opposed to the rate of mining.

Using the long-term arguments, articulated in paragraph 5.4.1, the mine could therefore increase production to reduce the number of periods and hence, the total period costs for the life of mine. Figure 5.4d depicts how maximum production through the concentrator should be maintained by sustaining the mine rate at that maximum. Note, however, that an additional stockpile will have to be built and reclaimed, increasing the unit operating costs again. Again the modelling principles allow for offsetting the incremental benefits against the costs.

---

Consider a unit variable loading & hauling:................ R1.75/t ore
Say only mining discontinues 1 month earlier due to 7500t ore/day mine rate increase:
- Ore to be stockpiled:................................ 7500t ore/day x 30.4 days/month x 12 = 2,74Mt
- Fixed costs savings: ................................ R5m x 1month made up @ 7500t ore/day = R5m
- Additional cost of stockpiling:.................. R2,39m (initial loading & hauling excluded)
- Monthly savings: .................................... R2,6m p.m. for 12 month's stockpiling

---

**Figure 5.4d. Playing off cost against the benefits of increased mine output (Palabora Focus Model, 1995)**

The period cost saving from this scenario is approximately 4.3%, which earns the mine the title of the savings bottleneck of the company.
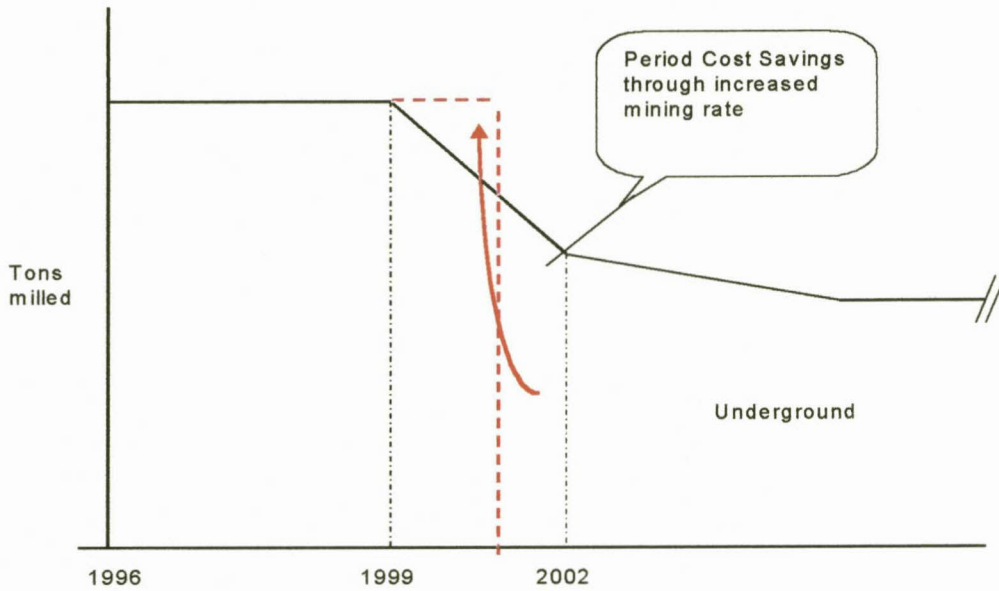


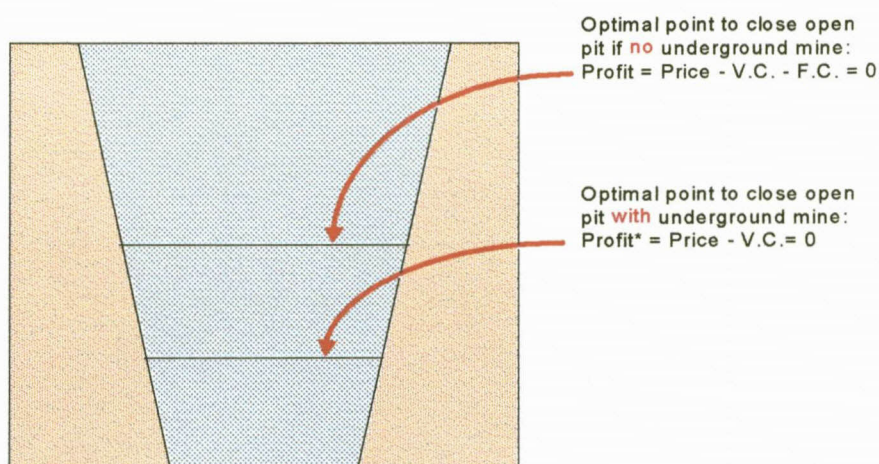**Figure 5.4e. Period cost savings (Palabora Focus Model, 1995)**

The savings potential does not end there. A further savings potential arises from the simultaneous operation of the open pit and underground operations. Figure 5.4f depicts the nature of the savings potential.
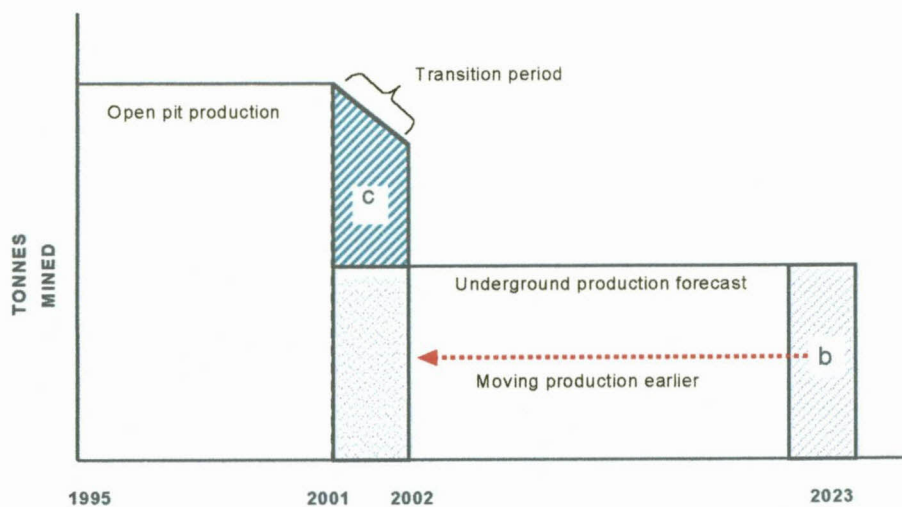
**Figure 5.4f. Moving the underground production forward (Palabora Focus Model, 1995)**

Thus overlapping the underground block cave mine with the open pit operation holds various opportunities.

- By mining deeper, even at the slower constrained rate after the underground mine has been commissioned effectively, brings the ore forward from the end of mine life of the underground mine. Figure 5.4g illustrates the effect on the ore reserve.

Optimal point to close open
pit if no underground mine:
Profit = Price - V.C. - F.C. = 0

Optimal point to close open
pit with underground mine:
Profit* = Price - V.C.= 0

* The fixed costs will now become part of the underground mine, so will the revenue.

**Figure 5.4g. Increased throughput from open pit to share fixed costs (Palabora Focus Model, 1995)**

- To put it in the simplest possible form, the open pit without an underground mine extension, will have to close down when the margins after accounting for returns approach are nil. Should the extension come about, a large portion of the fixed costs are shared and add to the savings potential.

- The probability of a possible dip in mine output can be minimised, and as such a constant cash flow ensured.

Goldratt's throughput constraint theory is to some extent supported by this thinking. Achieving the corporate goal is at the heart of the approach since throughput is maximised. But by calling it a savings bottleneck, the focus is turned away from just supporting the throughput bottleneck, which is downstream from the mine.

### (ii) Milling: The wealth bottleneck

The milling and concentrator section is the section where 16% of the copper mined is lost, and where it can be said that wealth is both created and destroyed. It is

logical that the traditional approach was to minimise those losses, a task easier said than done.

In the diagram below, some of the cause-effect relationships are shown to illustrate how a change in throughput through the milling and concentration section impacts on the wealth and not just short term profits.
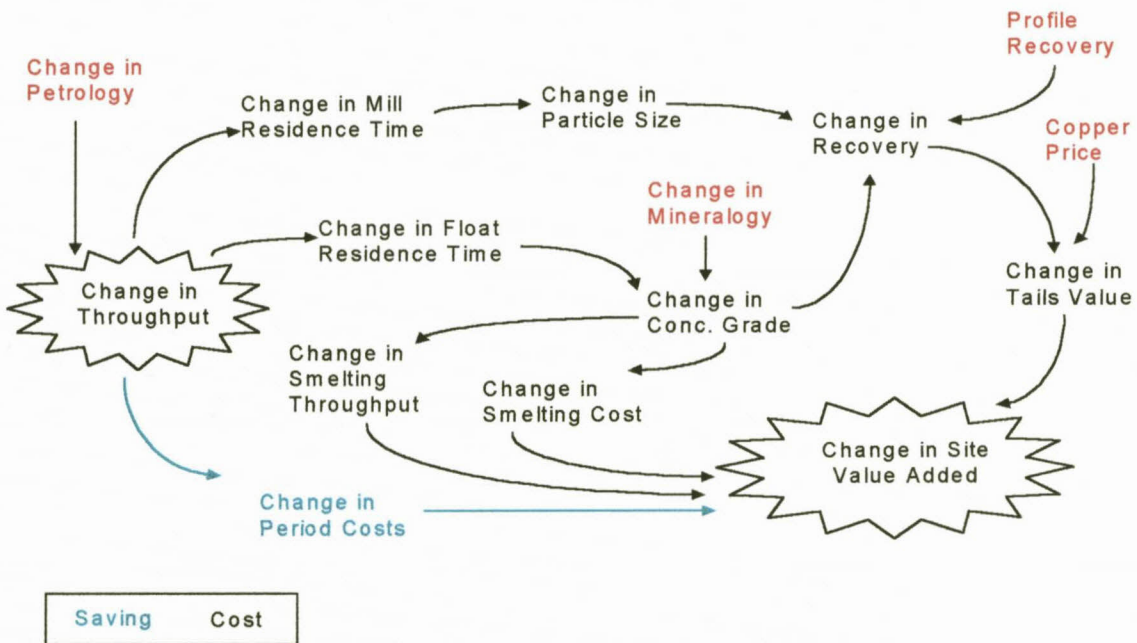


**Figure 5.4h. Cause-effect relationships in the value chain (Palabora Focus Model, 1995)**

In the absence of mine scheduling constraints (note that the milling section was the bottleneck relative to the mining capacity), changes in the mineralogical make-up might indicate a low percentage dolerite, making it possible to increase throughput through the mill section. A series of consequences result from these changes. These consequences, for example, the recovery profile, as well as further external factors such as the current or future copper prices might however, counter the initial decision to increase throughput. A fundamental insight gained from this is that only a completely integrated performance driver model will be able to support informed operational optimization.

The toughest aspect of convincing operations of this insight is that in the absence of such a model, the aim is to reduce variability of the whole process in as far as one

can foresee what will cause the next variance. The best practice at the time was to force processes into a stable throughput mode with expensive automation initiatives.

For example: the nominal mill throughput became a fixed set point subjected to the particle size of the cyclone underflow, or feed to the flotation section. The main objective is to maintain a constant particle size distribution that ensures the optimal recovery. It can be said that automation was aimed at <u>fixing</u> processes for predictable <u>efficiency</u> *in lieu* of <u>varying</u> the processes to maximise the <u>effectiveness,</u> albeit having done so unwittingly.
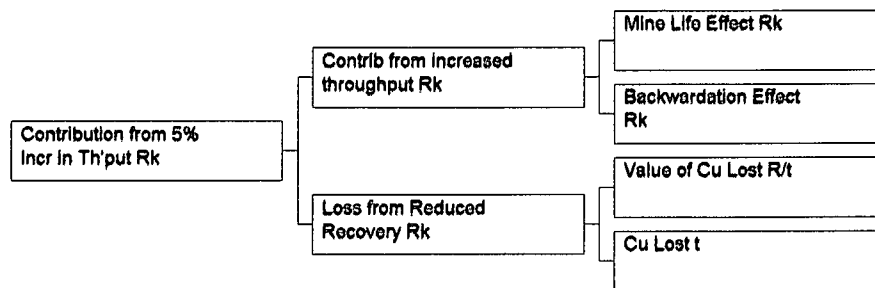
The problem with aiming at efficient process is that it is seen as the ultimate whereas optimising shareholder wealth should be the supreme objective. The causal diagram (fig 5.4h) suggests that if throughput is increased (i.e. varied as oppose to kept constant) various things happen:

- Recovery might reduce
- **since** more copper is lost through tails
- **and** the concentrate grade increases
- **therefore** the unit smelting costs increase
- **less** period costs result in period cost savings
- **and** if the market is in backwardation a higher contribution can be affected

If the net effect from increasing throughput amounts to higher yields of wealth, then certainly it should be the objective even if the short-term automation objectives might be violated. The fact remains that without a comprehensive view of the interrelationships, a throughput variance decision becomes impossible. Consideration should therefore be given to subject automation objectives to the economic objectives so that efficiency is maintained for corporate initiatives to be effective.

The following subset of the model illustrates the reasoning required behind the effectiveness of the organisation. The Focus® model became an ideal argument-building tool to assist in highlighting the play-offs that operations management are facing and need to understand. The size of the structure requires that one divide it up into levels. The top level is shown in figure 5.4i.

| | Mine Life Effect Rk |
| Contrib from Increased throughput Rk | |
| | Backwardation Effect Rk |
| Contribution from 5% Incr In Th'put Rk | Value of Cu Lost R/t |
| Loss from Reduced Recovery Rk | |
| | Cu Lost t |

**Figure 5.4i. Gains and Losses from increased throughput (Palabora Focus Model, 1995)**

On the one hand, a contribution is made, which is appropriately weighted to reflect the long-term views described earlier, as well as the current market price effect. On the other hand, a higher throughput results in a loss of copper through reduced recovery as the next graph illustrates (Palabora Focus Model, 1995).

**Throughput vs. % Recovery**
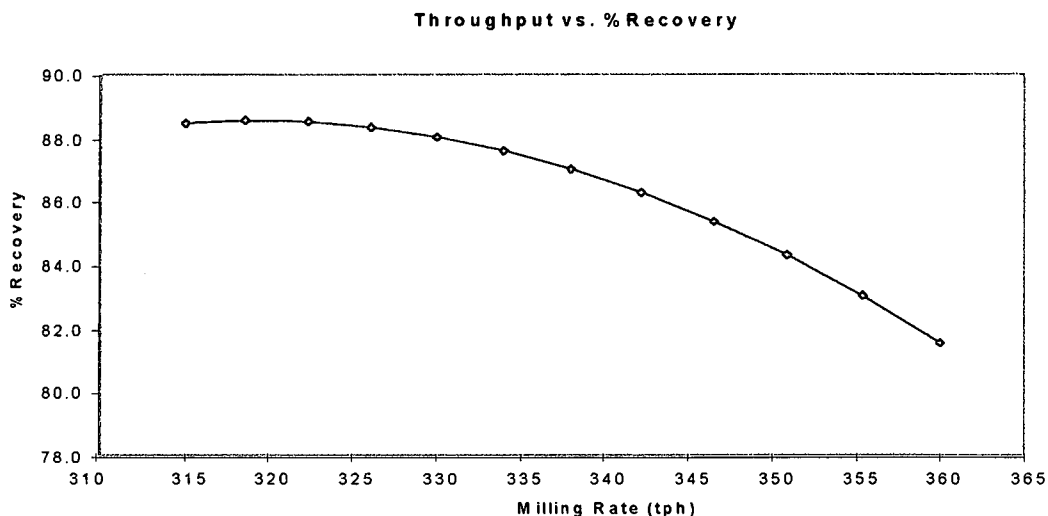
**Figure 5.4j. Throughput vs. recovery curve (Palabora Focus Model, 1995)**

Further investigation was required to understand ways of structuring the optimization models. Based on the %recovery vs. milling rate graph above, the following test model was drafted to investigate the cost-price-throughput-recovery inter-relationships for the rest of the open pit ore reserve. Calculations showed that it should take about 8.5 years to deplete the rest of the reserve, implying a certain throughput rate, and based on the throughput/recovery graph, a certain recovery. An increase in the throughput rate will reduce the life-of-mine; therefore, the period costs and recovery. The effects of variations in copper price, concentrate grade and

breakeven point were investigated during the study. Table 5.4b contains the data reflecting the assumptions above and leading to the subsequent calculations.

**Table 5.4b. Modelling assumptions**

| Modelling assumptions | | |
|---|---|---|
| Total ore reserve | 23,311 | kton ore milled |
| %Cu in ore milled | 0.5 | %Cu |
| % Recovery | 83.4 | %Rec (@ 354t/h) |
| %Cu in concentrate | 34.3 | %Cu |
| Cu Price | 10,000 | Rand/ton |
| Concentrate Cost | 3,623 | Rand/ton |
| Concentrate Value | 6,377 | Rand/ton |
| Fixed cost per annum | 289 | R million |
| Operating periods | 8 | Years |

| Evaluation of Value-added through reduced throughput based on Cu Price | | | | | | |
|---|---|---|---|---|---|---|
| | Period (yr) | Mill Rate /hr | Mill rate /day | %Rec | Total Cu recovered p.a. | Value of lost Cu @ Conc. Value (Rm) | Total Fixed Cost (Rm) |
| | 8 | 354 | 81,562 | 83.4 | 124,187 | 157 | 2,312 |
| | 8.5 | 334 | 76,954 | 87.6 | 123,004 | 111 | 2,457 |
| Variance | 0.5 | -20 | -4,608 | 4.2 | -1,183 | -46 | 145 |
| Variance % | | -5.6 | | | | | |
| Recovery offset: | | | 1.5% | | | | |
| Breakeven Recovery: | | | 85.0% | | | | |
| Equivalent Throughput: | | | 347 Tph | | | | |
| Daily Breakeven throughput: | | | 79862 Tpd | | | | |
| Required period: | | | 8.0 Yr | | | | |
| Current Cu Price | | | 10000 R/ton | | | | |

| Total production: | | 8yrs | => | | 993 Kiloton total |
|---|---|---|---|---|---|
| | | 8.5yrs | => | | 1046 Kiloton total |
| | | | Variance: | | 52 Kiloton total |
| | | | => | | 520 Rmillion |
| | | | | | Rmillion total fixed |
| | | | Minus | | 145 costs |
| | | | Value-added: | | 376 Rmillion |

The model derives the value-add as a result of the shortening of the life-of-mine from 8.5 to 8 years. As the copper price varies, the value-add levels will also vary, emphasizing the dilemma one is faced with if an organisation wants to optimise the complete value chain; conditions constantly change, and as a result, the goal posts

also change. The following graphs illustrate how the breakeven point changes with varying milling rates.

**Mill Rate vs. Break-even**
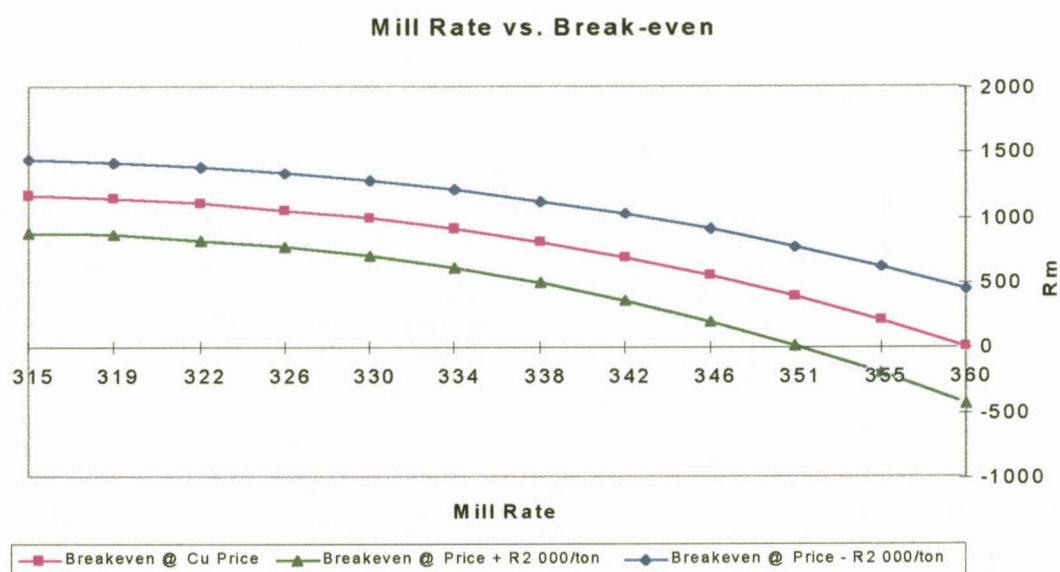


**Figure 5.4k. Milling Rate vs. Economic Breakeven Points  (Palabora Focus Model, 1995)**

As throughput increases, recovery decreases, which means that more copper is lost through tailings. It is therefore conceivable that at some point the revenue from increased production will be negated by the losses in copper, and that the situation will change based on the price of the metal.

These results confirmed that the following structure should be sufficient to track the value-add with varying conditions:
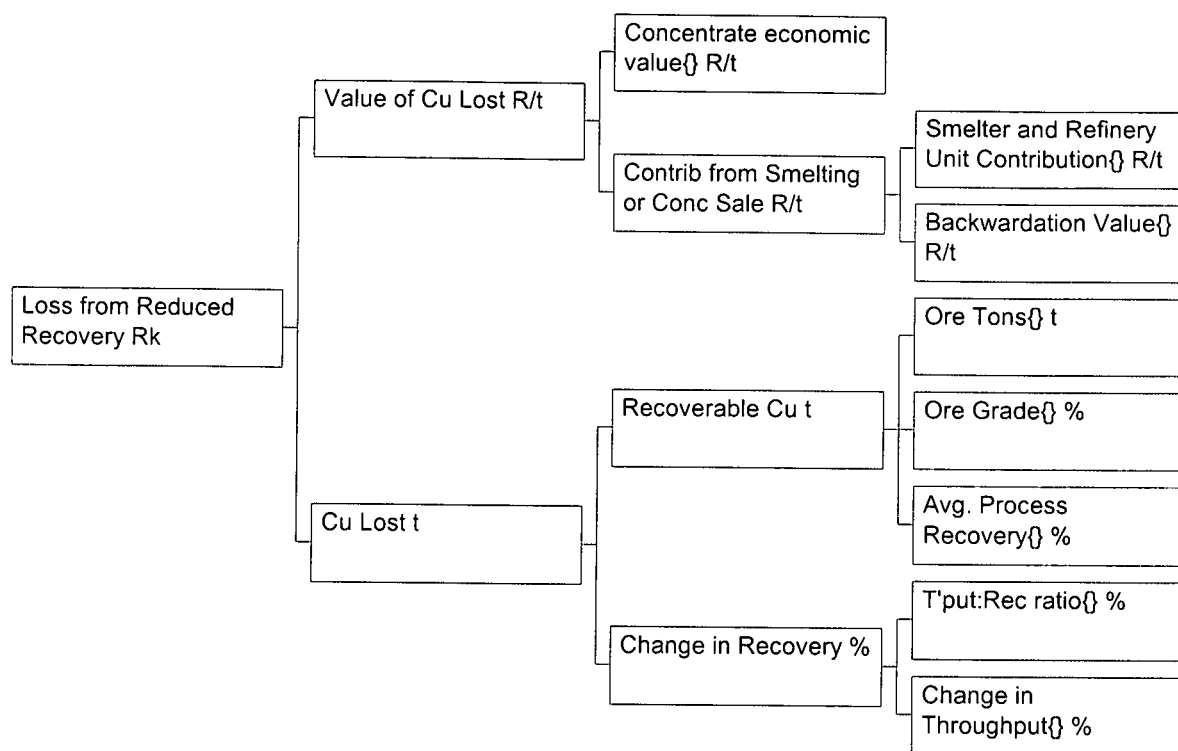
```
                              ┌─────────────────────┐
                              │ Concentrate economic│
                    ┌─────────┤ value{} R/t         │
                    │         └─────────────────────┘
        ┌───────────────────┐                        ┌─────────────────────┐
        │ Value of Cu Lost  │                        │ Smelter and Refinery│
        │ R/t               │         ┌──────────────┤ Unit Contribution{} │
        └───────────────────┘         │              │ R/t                 │
                    │         ┌─────────────────┐     └─────────────────────┘
                    └─────────┤ Contrib from    │     ┌─────────────────────┐
                              │ Smelting or     ├─────┤ Backwardation Value{}│
                              │ Conc Sale R/t   │     │ R/t                 │
                              └─────────────────┘     └─────────────────────┘
┌─────────────────┐
│ Loss from       │                                  ┌─────────────────────┐
│ Reduced         │                          ┌───────┤ Ore Tons{} t        │
│ Recovery Rk     │                          │       └─────────────────────┘
└─────────────────┘                ┌─────────────────┐  ┌──────────────────┐
                    │              │ Recoverable Cu t├──┤ Ore Grade{} %     │
                    │              └─────────────────┘  └──────────────────┘
                    │                          │       ┌─────────────────────┐
        ┌───────────────────┐                  └───────┤ Avg. Process        │
        │ Cu Lost t         │                          │ Recovery{} %        │
        └───────────────────┘                          └─────────────────────┘
                              ┌─────────────────┐     ┌─────────────────────┐
                              │                 ├─────┤ T'put:Rec ratio{} %  │
                              │ Change in       │     └─────────────────────┘
                              │ Recovery %      │     ┌─────────────────────┐
                              └─────────────────┘─────┤ Change in           │
                                                      │ Throughput{} %      │
                                                      └─────────────────────┘
```

**Figure 5.4l. Throughput: Recovery model structure (Palabora Focus Model, 1995)**

The "Cu lost"-branch is defined by the possible recoverable Cu tons based on the copper contained in the ore and an average empirical recovery % (Palabora Focus Model, 1995), and on the other hand, by the change in the expected recovery due to the change in throughput as determined by the throughput-recovery graph above. The value of the copper lost is, based on the backwardation arguments of section 5.2.1, either the smelting and refining unit contribution or the backwardation value, whichever is the largest.

The end result of these calculations is the <u>value of copper lost</u> due to the increased throughput which, as the initial issue map aimed at determining the contribution from a 5% increase in throughput will be, needs to be off-set against the counter-branch. This branch aims at establishing the contribution (which needs to be larger than the previous branch to make it a profitable endeavour). The counter-branch is depicted in figure 5.4m.
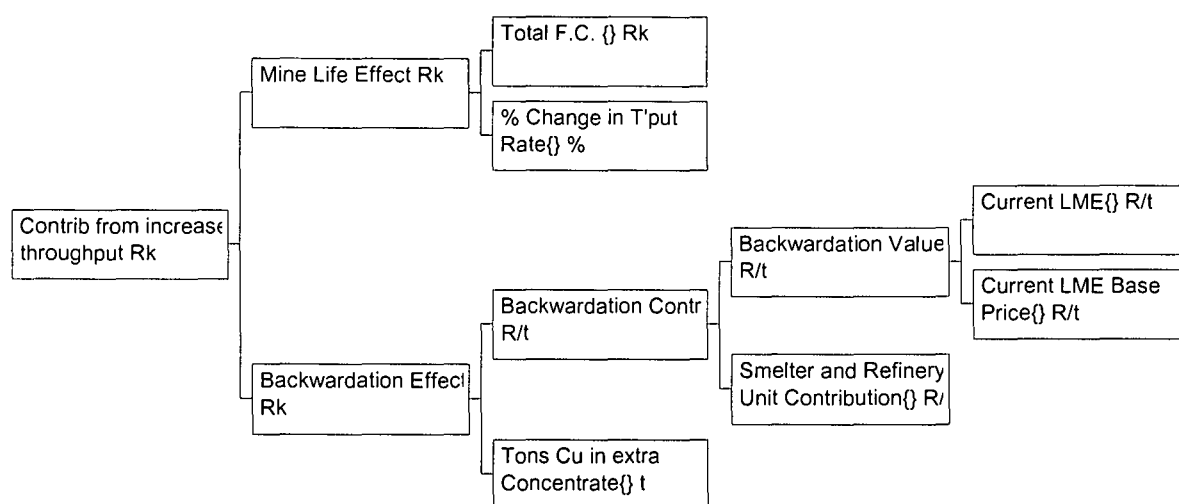
**Figure 5.4m. Long-term play-offs due to increased throughput (Palabora Focus Model, 1995)**

This branch adds up the total backwardation contribution with the savings in period costs by shortening the life-of-mine. This contributions is now offset in the initial structure to determine whether the reduced life-of-mine will be adding to the wealth of the organisation.

In conclusion, it is evident that the term "integration" spans across several dimensions in an organisation. In this instance, it also requires integrative thinking between those responsible for the geology, metallurgy and economics, as well as those responsible for automation of the process streams and those that have to find the most effective routes of leveraging these automated processes to the better of the organisation.

### (iii) Smelting: The profit bottleneck

The smelting and refining section adds further value to the intermediate product, copper concentrate. Two important aspects need to be recognised, namely, throughput and value-add. Throughput addresses the relative constraint to the upstream production capacity of the concentrate feedstock, whilst the value-add relates to the steps of improving the value of the feed material. The value-adding steps are:

1. Concentrate Economic Value – R5000 to R9000/ton, depending on the market conditions
2. Cathode Economic Value – An additional R600/ton to R1000/ton
3. Rod Economic Value – An additional R200/ton to R300/ton
4. Downstream potential also exists to manufacture goods from the rod products. This is a strategic move away from commodity production towards manufacturing.

Beyond the concentrate stockpile, every intermediate product can be traded at a premium and this will, therefore, add more profit to the corporate bottom line. The smelting and refining section can therefore be seen as a profit bottleneck under market conditions where backwardation is absent or below the threshold discussed earlier. Extending the value-adding steps therefore becomes strategically important.

## 5.4.4 Assessing Corporate EVA® with the Focus® model

Any study of this nature has to respond to the question: "If the financial reporting is as suspect as some say it is, what is your view on how we are actually doing? Has performance improved over the recent months?" And if the answer is positive the next logical question would be: "If so, how much of the improvement or deterioration is due to value-adding activities and how much is due to external factors?"

The Focus® model has generated the following high-level view of the performance of the company over 18 months. Observing the various bars, only the site value-add is substantial and indicative of any trend. No enhancements in Value-added were achieved by the marketing activities. Indirect costs may even indicate a slight increase, perhaps even a destruction of value.

## Short-Run Profit (EBIT) kR

Monthly Actuals Ending 1995
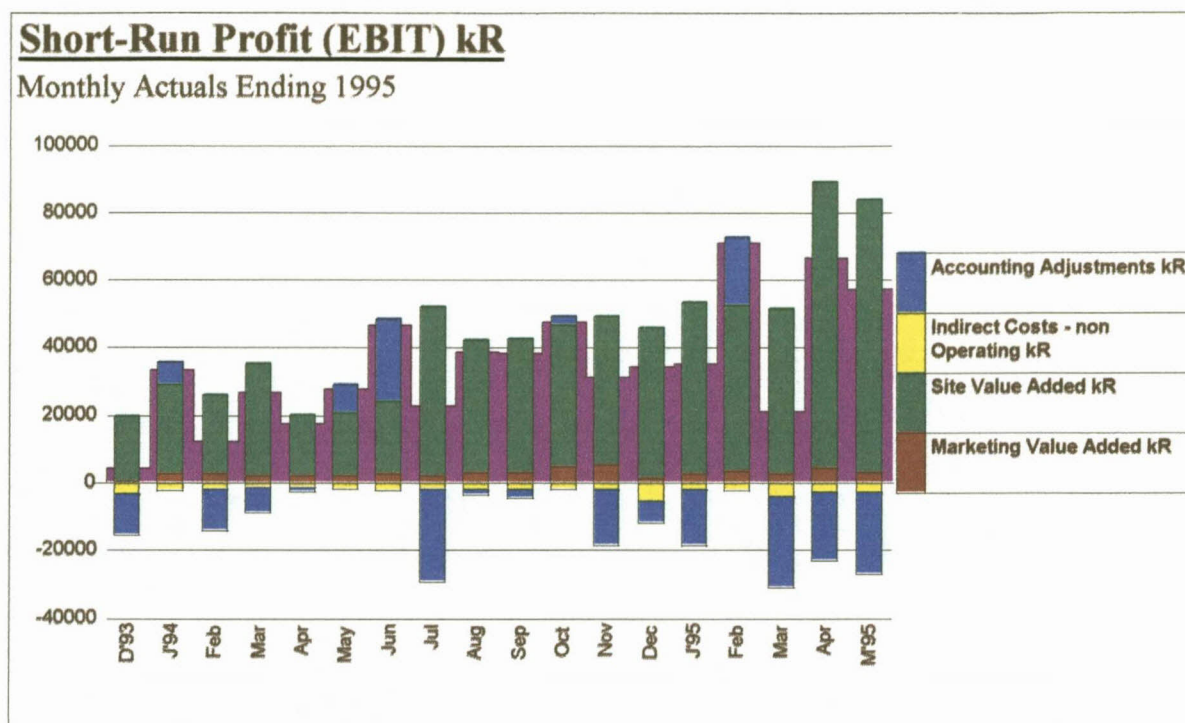


**Figure 5.4n. Profit drivers of the short-run profit trend (Palabora Focus Model, 1995)**

The "shadow profile" behind the stacked bars gives the summary of the other trends, generally showing an erratic but perhaps an upward trend. The accounting adjustment certainly introduces a "noise" that degrades the trend into the shadow profile.

One drawback of the Focus® model is that although it includes all the tangible drivers within the model, the design did not cater for separating out the external from the internal factors *per se*. Answering the questions posed above will need a different view of the business without falling into the accounting method trap discussed in the overview section. On the positive side, however, with a completely integrated data model, one could derive an assessment in the form of an issue map based on modern principles like Economic Value-add® (Stewart and Stern, 1991).

Using the structure of the model the initial and standard view was gradually stripped of the layers of external factor influences and "accounting misallocations" according to the EVA® view.

**Table 5.4c. An EVA® assessment of corporate performance (Palabora Focus Model, 1995)**

| Details | 1991 | 1992 | 1993 | 1994 | 1995 |
|---|---|---|---|---|---|
| Net Sales | 944 | 928 | 885 | 1153 | 1484 |
| Cost of Goods Sold | 455 | 519 | 576 | 625 | 669 |
| Stock Variation | 10 | 37 | -22 | -31 | -33 |
| Depreciation | 36 | 41 | 54 | 50 | 68 |
| Gross Profit | 488 | 409 | 309 | 528 | 815 |
| Selling General & Admin | 44 | 47 | 53 | 113 | 130 |
| Net Operating Profit | 444 | 362 | 256 | 415 | 685 |
| Interest Expense | 0 | 25 | -8 | -7 | 6 |
| Other income | 15 | 10 | 8 | 13 | 2 |
| Income Before Taxes | 458 | 397 | 256 | 421 | 693 |
| Taxes | 229 | 199 | 128 | 210 | 346 |
| Net Operating Profit After Tax | 229 | 199 | 128 | 210 | 346 |

| Capital | 988 | 907 | 867 | 986 | 1213 |
|---|---|---|---|---|---|
| Balance Sheet | 830 | 787 | 700 | 720 | 756 |
| PLUS: Adjustments (Nibculs*) | 158 | 120 | 167 | 266 | 456 |
| Creditors | 58 | 79 | 81 | 116 | 109 |
| Taxation | 100 | 1 | 49 | 102 | 248 |
| Dividends | 0 | 40 | 37 | 48 | 99 |

*Nibculs – Non Interest Bearing Current Liabilities

Table 5.4c shows how the Net Operating Profit After Tax, according to the EVA® approach, indicated a 13% drop from 1991 to 1992, and a further 36% drop towards 1993. Thereafter the trend turned around and the economic value improved by about 51% from 1991. According to this standard assessment the performance trend is sound and management should be rewarded for a job well done.

The question was raised at this point as to whether this is a fair reflection of what value the organisation has added to the mineral resource. Two important factors that the accounting view of the business is not considering are the market copper price situation, which was in backwardation at the time, and the head grade or the ore grade into the beneficiation plants. These factors are windfalls over which management has had no control (the head grade movement relative to the previous years' average is a result of the changing pit geometry).

**Corporate EVA Performance - Base EVA Case**
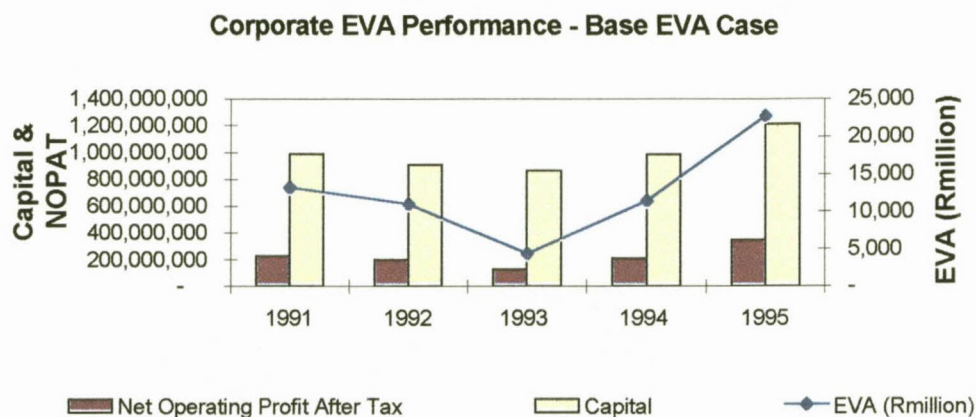


Figure 5.4o. Base Case of EVA® assessment (Palabora Focus Model, 1995)

After discounting for the movement in the copper price relative to the 1991 price, i.e. discounting both for a risk-free escalation rate, as well as any additional supply-demand driven increases, the corporate performance looked remarkably different:
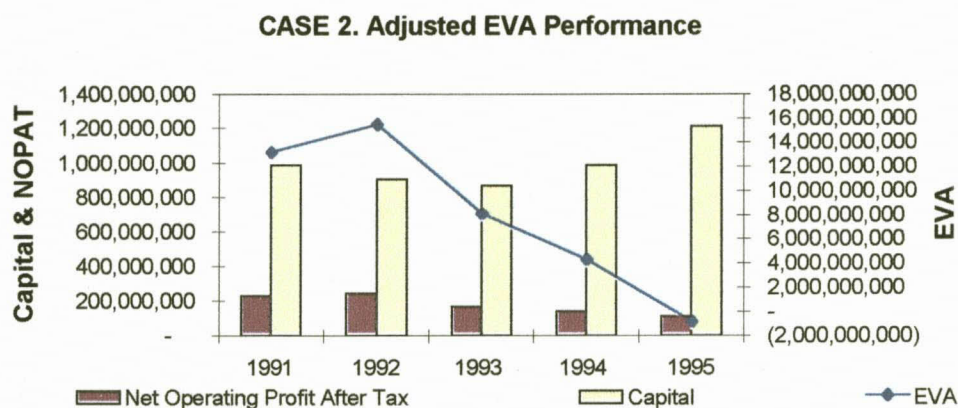
**CASE 1. Adjusted EVA Performance**
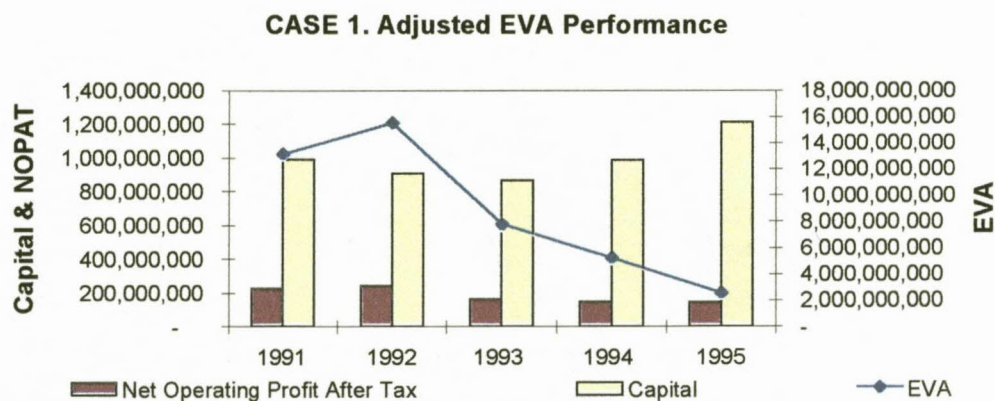


Figure 5.4p. Base Case adjusted for copper price changes (Palabora Focus Model, 1995)

The NOPAT now decreases over the last four years and the economic value-add has shrunk at an alarming rate. By discounting for the increasing head grades at the same time accentuates the problem further. The actual economic value-add declined into negative territory, suggesting that value is actually being destroyed.

This alarming trend underlines the dilemma that management teams have to confront, i.e. that the reporting system may mask the real facts. One could argue

that even the view presented here could be shown to be imperfect in times to come, and hence, what are management teams to do. A soundly integrated model that allows organisations to take various views based on certain sets of assumptions of the business will certainly be one attempt to understand the reality of business even better.

**CASE 2. Adjusted EVA Performance**



**Figure 5.4q. Case 1 adjusted for ore grade increases (Palabora Focus Model, 1995)**

These results, together with the powerful continuous improvement support system with its completely integrated key performance trees, are testimony to the insight that can be gained into the world of business. Identifying the key performance driver set paves the way to a progressively increased understanding of the business. Based on these fundamentals, investigating new views of the business becomes possible, as will the ability to support the arguments forthcoming from such investigations. Without sound, compelling arguments, executives cannot be expected to risk fundamental changes like those of restructuring the financials of the organisation.

The following section will suggest further changes required to leverage the investment of time and money into understanding the business better. After all, why investigate new ways of doing business and not implement them? One compelling reason certainly is the risk imposed on the CEO who believes that the new ways will improve the organisation's performance. Making people "see" and adopt the new approach is still the biggest hurdle to improved performances today.

# 6  Enhancing corporate alignment

The stable, inflexible nature of mature organisations makes them successful whilst the environment is stable; however, this characteristic makes it difficult to turn around when the environment changes. People, business processes and systems resist change imposed on them whether such change is needed or not. The findings of the work of two strategists, Hofer and Schendel (1984), is particularly relevant to business:

> *"Because of the paucity of strategic challenges, many business-level strategic planning processes evolve into sophisticated budgeting systems that (actually) assist in the implementation of strategy. To the extent that this happens, they become increasingly incapable of distinguishing between tactical and strategic challenges"*

Turning this question around and asking whether this applied to the company dealt with in this study, we invariably focused on Palabora. Palabora has been operating in a copper market that required it to keep costs down, improve capacity constraints and maintain healthy industrial relations. Considerable internal changes face Palabora with the establishment of an underground mine. Strategic changes will have to be made to maintain profit margins and the whole organisation will have to be aligned to the requirements of the new mine. This requires a clear focus, sound communication and a committed work force; indeed, these three require a simple, effective management system.

Through an effective management system, the strategic direction can be translated into action plans, which will align the work force through an open communication system. The business modelling project became an ideal opportunity to revisit the planning process and introduce the Focus® model into it.

## 6.1 Future planning at Palabora

Prior to 1996, strategic planning had been undertaken annually and concurrently with action planning and budgeting. Palabora was relatively stable amidst the political transition and was performing well and therefore, had little need to undertake major annual strategic changes. In addition, running the strategic and action planning sessions concurrently limited the time available for effective strategic planning to the extent proposed in this section. As a consequence, the strategic planning session outcomes had a fairly loose link to the action planning and budgeting.

To overcome these limitations in the light of an expected increase in changes in the business environment, strategic planning has to be separated from action planning and budgeting. The key conditions of this separation include the following:

- The development of the strategic plan *should precede and drive action planning and budgeting.* The short-term objectives, short-term targets and improvement programs in the action plan should be developed to be consistent with the objectives, targets and direction set out in the strategic plan. The key outputs of the strategic and action planning process are set out in figure 6.1.

- The strategic planning process should occur during the first 6 months of the calendar year in which the process is undertaken. During this time the preparation phase, as described below, can be completed in time for the first strategic planning session.

Some specific objectives are set for the adaptation of the corporate planning system to cater for the newly developed key performance drivers.

## 6.2 Objectives of planning system adaptation

The planning system is aimed at enhancing the corporate management system by:
- Affecting how employees will be *aligned* with the strategic direction as they are

involved in the continuous improvement, planning and execution,

- Providing a simplified structure and establishing *links* for critical tasks between different layers of management by means of the layered performance drivers,

- Fine tuning the way that the Focus® model will assist in *identifying, prioritising and monitoring* progress on key profit drivers,

- Suggesting the way that the Focus® model can assist in *closing the management loop* through measuring performance for a gain sharing scheme.

These objectives are the basis of the key features of the implementation changes described in the next section.

## 6.3  The key features of the implementation of the planning system

Following from the above, some key features of a world-class planning system become evident:

- The development of divisional plans by *translating the mine strategies* into divisional objectives, which *specify clear personal accountabilities* down to supervisor level on a top-down basis.

- Establishing the key performance drivers (KPDs) and the relationships between the KPDs and the performance assessment measures of the organisation. *Consensus* about which factors drive the profitability of the business should be reached in divisions through teamwork sessions and cannot be delegated to a technical person for definition. Where consensus has not been reached, research should be initiated in order to test hypotheses. To eradicate "local optima", senior management should jointly review divisional KPDs. An example of a local optimum would be to save on blasting costs at the expense of the optimum blasting fragmentation. Accountabilities for KPDs must be clear and be reported on. The Focus® model should be updated with the selected KPDs for monitoring and planning purposes.

- Inclusion of *best practice performance benchmarks* and the use of technical or scientific limits as the basis for determining the degree of stretch in performance improvement targets. In order to ensure that the process of selecting performance improvement targets is rigorous, every department should develop a performance driver tree, which links the significant operating activities to the corporate cash flow. The performance driver tree forms the basis of a simple financial model, which the business unit can use to project wealth creation performance as oppose to short-term profit performance.

- Developing/refining the *performance driver tree* and the simple financial model are necessary preparatory steps. This work should be completed prior to the start of the strategic planning process.

- Establish explicit and quantified linkages of the *critical tasks* of individuals and groups of individuals to the objectives of the division, both within and between the strategic planning and action planning and budgeting processes. Rigorous development of these linkages of critical tasks through a cascading process will make personal accountabilities clearer. The quantification of the impact of planned improvement activities will enable more systematic monitoring of performance against targets.

- Use of *workshops* during the development of both strategic plans and actions plans and budgets to develop a shared understanding of the need to improve and to build individual commitment to plan objectives, targets and actions at all management levels (managers to supervisors). Workshops also provide an opportunity for peer interaction. Each manager should ensure that all relevant managers participate as required in both the strategic planning process and the action planning and budgeting process.

## *6.4 Critical Success Factors of the Planning System*

The critical success factors of the Corporate Planning System, which are those factors that must be maintained properly to be successful with the main objective(s), are as follows:

- The existence of a **logical planning sequence** with **specific intermediate deliverables** during the whole planning process; each deliverable should be useful to the targeted users.

- The organisation must **involve lower levels of the organisation** in the planning process to establish **corporate wide alignment**.

- To this end, certain key tasks and variables should **cascade** down the organisation to provide links between the layers of management. The result is an **integrated plan** that spans all the layers of the organisation.

- Clear **accountabilities** for each task and variable in each layer of the organisation should be assigned and reported against,

- To close the management loop, **performance-related pay** should be instituted to re-enforce the accountabilities.

## *6.5 Key documents of the Planning Process*

Figure 6.1 illustrates the reviewed Mine Planning Process. The management cycle has five broad steps namely:

(i)     Preparation (for Strategic Planning)

(ii)    Strategic Planning

(iii)   Action Planning and Budgeting

(iv)   Execution and

(v)    Performance Monitoring

The main planning documents are shown in figure 6.1 as the respective outputs from planning activities. The phases are:

## PHASE 1: PREPARATION

**Outputs:**

- Key performance drivers
- Best practices analyses
- Market assessment and
- Corporate Performance Summary
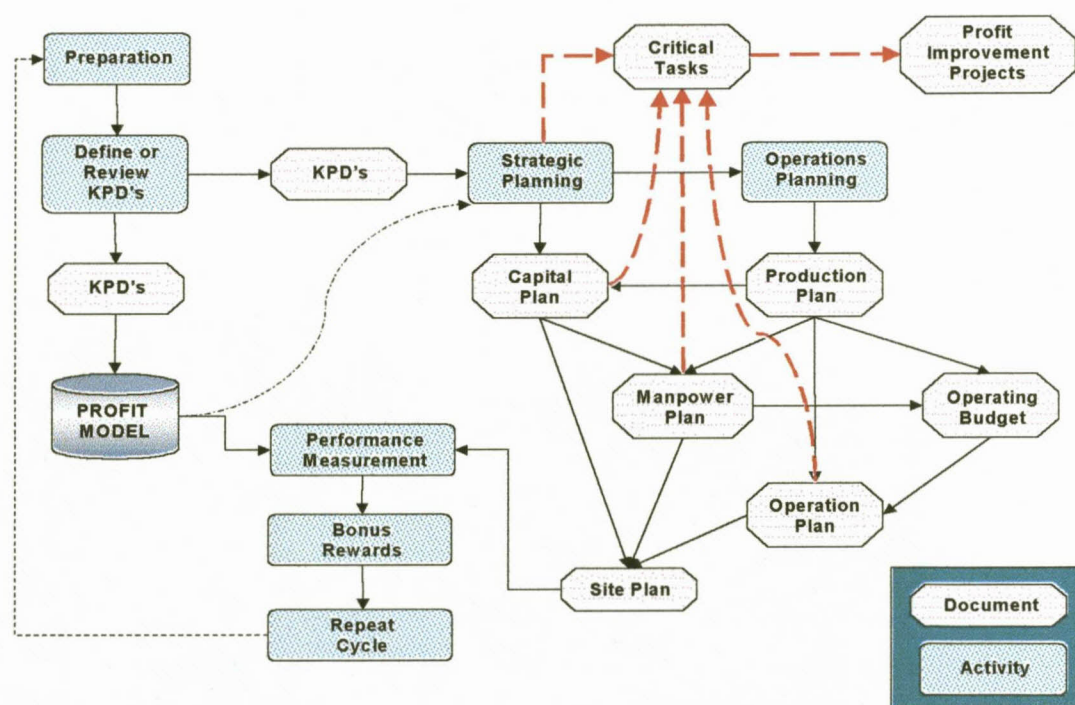


**Figure 6.1. Flow diagram of the Corporate Planning Process (adapted from the CRA Planning Manual)**

## PHASE 2: STRATEGIC PLAN

**Inputs:**

- Key performance drivers
- Best practices analyses
- Market assessment and
- Corporate performance summary

**Intermediates:**

- Quantified objectives for stakeholders
- Strategic opportunities and obstacles
- Options analyses
- Targets for KPDs
- Potential for improvement assessment
- Critical tasks: actions, milestones and accountabilities
- Profit improvement projects: project and capital plans

**Outputs:**

- Strategic direction as stipulated in **Site Plan**

## PHASE 3: ACTION PLAN AND BUDGET

**Inputs:**

- Short-term planning context: **Production Parameters and Estimates**
- **Targets for KPDs**
- **Critical tasks**: actions, milestones and accountabilities
- **Profit improvement projects**

**Outputs:**

- **Mine plan (consisting of production, manpower & capital plans, operating budget)**
- Short-term actions and accountabilities in the form of a **critical tasks hierarchy**

## Preparation for Strategic Planning Sessions

Prior to commencing with the planning process, the divisions should identify a limited number of key performance drivers. These key performance drivers will provide the internal focus for assessing the divisions' current competitive position in the strategic process. Key performance drivers should be clearly described so that all supervisory and management levels have a common understanding of the focus for improvement. Key performance drivers are selected based on the relative degree of economic leverage[1] and potential for improvement that is associated with each discrete activity.

To understand the improvement potential, the divisions should undertake further research into those performance drivers with high (positive or negative) economic leverage. Carefully selected benchmarking comparisons have to be performed to quantify the gap between the division's performance and 'world best practice', and to identify practices that will lead to excellent performance. In addition, the division should identify technical and scientific limits for these performance drivers, where appropriate. Once the division has gathered information on 'world best practice' and technical limits, the managers should select and agree on the key performance drivers according to the process described in Section 3.

## *6.6  Strategic planning with Key Performance Drivers*

The following section reflects a fairly standard approach to strategic planning at mines in modern times. In the late 90's CRA, an Australian mining company embarked on a revamping process of their strategic planning processes. When the amalgamation of CRA and Rio Tinto Zinc took place, the outcomes of this

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[1] Economic leverage is expressed as %change in profit per %change in a performance driver. As example, say, a performance driver has a leverage of -0.9. It means that for every one percent change in the performance driver, the profit of the company will *decline* (negative leverage) by 0.9 percent.

improvement project became available to Rio Tinto Zinc, and hence to Palabora Mining Company. The processes were then adapted for application at Palabora.

The adapted processes became part of the suggested rollout process of the Palabora Focus® Model at the company. The importance of the diligent adherence to the process cannot be overemphasized. As a result, it was considered equally important to include the strategic planning processes into this document.

## 6.6.1 Strategic Planning Objectives

The goal of effective strategic planning is a challenging and sustainable strategic direction which meets stakeholders' expectations and to which managers are committed. To achieve this goal, all relevant management levels in the divisions must be involved in taking appropriate steps during the strategic planning process; this is done by:

- Setting challenging quantified *objectives* for up to 6 years in the context of stakeholder expectations.

- Identifying the *opportunities and obstacles*, which influence the division's ability to achieve its objectives. This can be considered in the context of:

  - The outlook for the industry, market segments, and other external factors.
  - The division's performance benchmarked against 'world best practice', or technical and scientific limits.
  - Those systems and processes, which constrain the division and organisation from improving its performance.

- Developing rigorous assessments of scenarios for those *uncontrollable* factors that are likely to have the greatest impact on the sustainability of the strategic alternatives and hence strategic direction.

- Developing *critical tasks* with milestones for up to six years ahead with clear personal accountabilities across supervisory levels that satisfy the mine's objectives. These plans should be flexible enough to cope with the range of uncertainty that the organisation could face. In light of these plans, the organisation should also highlight any selected strategic alternatives that lock the organisation into or out of alternative strategic directions as well as the rationale for selecting these alternatives.

The remainder of this chapter describes the strategic planning process in more detail, proposes the required involvement in developing the plans, outlines indicative timing and sets out a possible implementation approach that the organisation may wish to use to develop their strategic plans.

### 6.6.2 Strategic Planning Process

The strategic planning process has five linked phases (Table 6.1). The purpose and key elements of each stage are described below. While these phases will be described in sequence, it is important to recognise that the process is iterative.

### 6.6.3 Develop challenging quantified objectives

The starting point for strategic planning is a set of challenging quantified financial and non-financial objectives, which clearly position Palabora with regard to its copper cathode and rod, zirconia and vermiculite for the long term. Objectives should cover a time frame of up to 6 years, meet shareholder expectations, and satisfy the reasonable expectations of its other stakeholders. The following steps are required to develop these objectives.

- ***Develop Terms of Reference.*** Palabora's strategic planning should be undertaken in the context of the strategies for its holding company. The Terms of Reference describe how Palabora fits in with the holding company's strategy for the industry and set out its strategic financial and non-financial expectations for a time frame of up to 7 years. *This assessment should be*

*done in preparation of a first strategic planning work session and the results presented at the meeting.*

**Table 6.1 Strategic Planning Process (Adapted for Palabora from CRA Manual)**



| PLANNING STAGE | Preparatory | Workshop I | Workshop II | Workshop III | Workshop IV | Workshop V |
|---|---|---|---|---|---|---|
| **Key steps** | • Performance driver tree development<br>• Benchmarking exercises<br>• Establish market conditions<br>• Assess corporate competitiveness | • **Identify key stakeholder** groups other than Company<br>• Assess **expectations** of key stakeholders<br>• Define broad **objectives** for Palabora & divisions (financial as well as non-financial) | • Assess/Review situation<br>- Market situation<br>- Company's competitive position<br>• List opportunities<br>• Prioritise<br>• List Obstacles<br>• Prioritise | • Identify feasible options for each objective using the success criteria AND using the **Big Five classes of critical tasks:**<br>- SHERQ<br>- Competitive-ness<br>- Organisational Development<br>- Business Systems<br>- Technological capability | • Review/assess the evaluations of strategic options:<br>- Cash Flows<br>- Check Success Criteria and prioritise options<br>- Test against objectives<br>• **Allocate resources** to options<br>Set **Strategic Direction (prioritised options, resources)** | • **Select** acceptable strategic options<br>• Firm up on strategic direction **(prioritised options, resources)**<br>• Develop **critical tasks**<br>• Review selection of key performance drivers and set stretching **targets**<br>• Review strategic plan against objectives |
| **Key inputs** | • Training<br>• Palabora Planning Manual<br>• Planning schedule | • Company policy<br>• Key Performance Drivers<br>• Business assessment<br>• Mission & Vision | • Broad Palabora and divisional **objectives** for stakeholders (financial & non-financial) | • List of **issues** (opportunities and obstacles) | • **Evaluations** of strategic alternatives (Cash Flows, IRR's, Scenarios for non-financials) Benchmark results | • Strategic direction **(prioritised options, resources)**<br>• KPD's |
| **Key outputs** | • Limited number of key performance drivers (80:20 principle)<br>• Benchmark results<br>• Market & Competitive-ness assessment | • Purpose statement<br>• Broad Palabora and divisional **objectives** for stakeholders (financial & non-financial) | • List of **Success Criteria** for each objective<br>• List of **issues (opportunities and obstacles)** | • List of **strategic options** | • **Strategic direction (prioritised options, resources)**<br>• Targets for KPD's | • Strategic plan **Purpose statement,**<br>- **Objectives,**<br>- **Options,**<br>- **resources,**<br>- **critical tasks** *with* milestones, accountabilities<br>- **KPD targets** |

- ***Assess expectations of key stakeholder groups other than the holding company.*** The previous step assessed the expectations of the shareholders. Management should also identify stakeholder groups that have a significant interest in Palabora's performance and review/assess the expectations of

these groups prior to developing challenging objectives. These groups should include, at a minimum, private shareholders, customers, employees, principal suppliers, community groups and governments. *A set of stakeholder expectations should be prepared and presented to the work session for review and use in defining the objectives.*

- **Define challenging objectives.** With all the above in mind, review the Corporate Mission and Vision statement, and then define challenging objectives for the organisation for a 3 to 6 year period. As an acid test the following questions can be used:
  - o *"Are all stakeholders' expectations addressed by the set of objectives?"*
  - o *"Can the company's mission and vision be fully accomplished through these objectives"*

## 6.6.4 Identify opportunities and obstacles

After determining objectives for Palabora, the management team should identify the current and impending opportunities and obstacles, which influence the company's ability to meet its objectives.

Opportunities and obstacles should be developed from an assessment of the situation that Palabora faces and how it compares with the world's best practices. As described below, this situation assessment should cover an analysis of the outlook for relevant external factors and an analysis of Palabora's current competitive position. Having completed these analyses, management should take an integrated external and especially internal perspective to identify the most important opportunities and obstacles, collectively called **issues** for the remainder of this document.

(i) *Develop perspectives on the outlook for relevant external factors.* A framework, which describes these factors in more detail, is shown in table

6.2. Factors which should be considered include forces external to the industry, components of the structure of the industry, trends in customer behaviour and the apparent strategies of competitors at the bottom of the cost curve, those at the top of the cost curve and any others like national and local government who are major players and/or who are undergoing significant change. *This assessment should be done in preparation of a first strategic planning work session and the results presented at the meeting.*

**Table 6.2. A framework to review the Industry Dynamics external to the organisation (Adapted from the CRA Planning Manual)**



| EXTERNAL SHOCKS | STRUCTURE | CONDUCT |
|---|---|---|
| **Technology breakthroughs** **Changes in government** **Policy/regulations** **Underground decision** | **Economics of demand** <br> • Availability of substitutes <br> • Differentiability of products <br> • Rate of growth <br> • Volatility/cyclically <br> **Economics of supply** <br> • Production capacity <br> • Import parity <br> • Diversity of producers <br> • Fixed/variable cost structure <br> • Capacity utilisation <br> • Technological opportunities <br> • Cost curve <br> **Industrial chain economics** <br> • Bargaining power of customers <br> • Monopolistic status perception <br> • Traditional partnerships | **Capacity change** <br> • Acquisition/disposal <br> **Vertical integration** <br> • Forward/backward integration <br> • Vertical joint ventures <br> • Long-term contracts <br> **Internal efficiency** <br> • Cost control <br> • Process R&D <br> • Automation <br> • Process Simplification <br> **Marketing** <br> • Pricing <br> • Volume <br> • Advertising/promotion <br> • New products R&D <br> • Distribution |
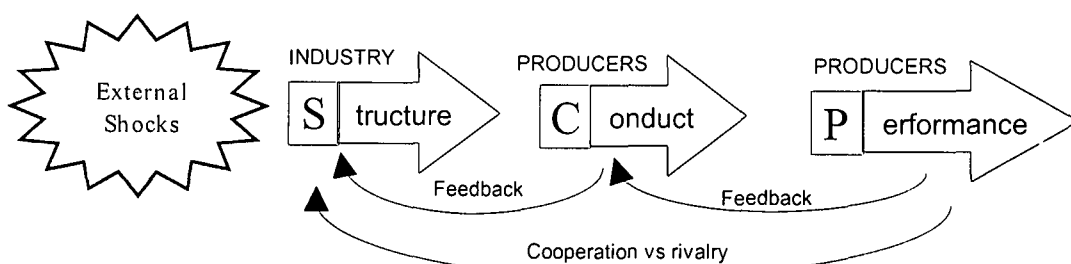
*(ii)* ***Assess the business unit's current competitive position.*** The ability of Palabora to compete successfully in the industry will depend on its ability to keep its costs down and to maintain or improve its position in the respective markets through marketing efforts and technological advances. *The preparatory best practice comparison exercises' results will, however, assist in identifying the gaps between the organisation's and the industry's best performances for the relevant variables.*

*(iii)* ***For each objective stated in the previous section, define the criteria, which should be met for those objectives to be successfully achieved.*** Consider the following example of an MRM objective:

*"To exploit the optimal extraction of the ore reserve according to the market conditions and requirements by involving all the disciplines in the organisation to the full"*

The relevant criteria and the related processes or systems could be:

**Table 6.3. Criteria and Processes for aligning work force (CRA Planning Manual, 1994)**

| Criteria | Process or System |
|---|---|
| • Establish clear targets that are... | • Key performance driver hierarchy |
| • Continuously and clearly communicated... | • Cascading, three-way communication system |
| • In a way that creates ownership... | • Gain-sharing, Accountability for KPD's, etc. |
| • Amongst all employees | • Cascading, three-way communication system |

*(iv)* ***For each criterion defined above, define the opportunities and obstacles that exist.*** To assess its ability to influence Value-addition, price and delivered cost, the company will need to have a good understanding of its current market position and the potential to improve in the areas of its internal economics, human resources, skills, technology, and information systems. To develop this understanding, the company should identify the systems and processes which directly or indirectly

impede its ability to improve the performance of the identified key performance drivers (See table 6.3 above). *The preparatory best practices comparison exercises should help to identify systems and processes that need to be changed, actions to be taken or projects to be launched.*

IMPORTANT NOTE: In periods of few or negligible changes in the environment of the organisation, strategic planning could be done less regularly. However, changes in senior management structure or in times of transition as in the case of the underground mining development, annual assessment might be required to optimise the strategic direction taken.

## 6.6.5 Identify strategic options

Divisional managers should develop a set of feasible alternatives to capture the opportunities and overcome the obstacles. In some cases, only one course of action may appear to be feasible. While this situation may occur often, managers must exercise judgement to ensure that potential alternatives are not discarded prematurely.

As shown in the above example illustrating the definition of criteria, the strategic options (shown as system or process) are derived from the criteria that have to be fulfilled for the objectives to be achieved. An example of an aspect *external* to the business should enhance the illustration:

*"To maximise shareholder wealth by adding Value-added processing to the existing production line"*

The relevant criteria and the related strategic options could be:

**Table 6.4. Example of Criteria and Options (Palabora Focus® Project, 1995)**

| Criteria | Options |
|---|---|
| • According to Holding Company policy | • **Additional products** |
| • Only synergistic processes | i. Copper tube manufacturing |
| • Market opportunity should exist | ii. Magnetite: Sponge iron, heater blocks |
| • Should enhance customer service | iii. Vermiculite: Fire boards, Sound Panels |
| • Create jobs for local community | • **Retention of existing market** |
| • Should be environment friendly process | iv. Zirconium Basic Sulphate |
| | v. Secure copper metal for producing rod in post 2002 (and copper tubing), etc. |

## 6.6.6 Option Evaluation, Selection and Prioritising

An analysis should be performed to determine the value-creation potential or organisational impact of each option. Managers and technical staff should make an assessment before presenting to the senior management team at the third workshop (Refer to Table 6.1). The evaluation by senior management as described in the following paragraph, should be focused on selecting and prioritising the options that contributes to meeting the objectives. *The allocation of resources, responsibilities and time schedules at this point is essential since it forms the basis from which corporate alignment takes place.*

### 6.6.6.1 Preparation

The assessment of the options by managers and technical staff could be undertaken in the following sequence:

*(i)* ***Identify key uncontrollable and controllable determinants of the cash flow.*** This step identifies those uncontrollable and controllable determinants of cash flow, which will have the greatest impact on value-

creation potential. *Key uncontrollable determinants* are selected by assessing their degree of economic significance and the uncertainty of the range of future outcomes. *Key controllable determinants* are selected by assessing their degree of economic significance and the potential for change. The Focus® model is helpful in this selection if the strategic alternative is related to existing activities. *However, where the alternative is outside the scope of the company's current activities, a new performance driver tree or framework will need to be developed.*

(ii) **Develop scenarios for each <u>uncontrollable</u> determinant.** These scenarios should be based on an understanding of the underlying variables. For example, if the price of copper were a determinant of cash flow, then it would be important to base the evaluation on a distribution of future prices rather than a single point estimate. This forecast distribution should be based on a forecast of future demand and supply scenarios.

(iii) *Identify change potential for each <u>controllable</u> determinant.* The change potential should be based on an understanding of 'world best practice' performance and management's judgment about how quickly the business unit can move towards this level of performance. *The comparative exercise during the preparatory phase is aimed at supporting this particular assessment.*

(iv) **Determine value-creation potential.** This final step evaluates the alternatives by determining the value-creation potential **and** assessing the associated risks. To do this, it is necessary to calculate a range of cash flows based on the analysis of the key determinants of cash flow.

*The results should ideally be presented to senior management by the staff that did the analysis of the options. This will enhance the quality of the analysis and generate ownership for the proposed strategic actions.*

## 6.6.6.2 Evaluation, Selection and Prioritising

Management should determine an appropriate set of strategic actions based on the results of the analyses prepared by line managers and technical staff. The set of strategic options should satisfy **three criteria**:

- Each option will **create value** for the organisation, given the likely uncertainties.

- The aggregate capital expenditure required for the selected set of strategic alternatives is acceptable in light of the **capital expenditure level** which is available and for which adequate **resources** exist to execute the actions requiring the capital.

- The alternatives satisfy the company **objectives**. If this is not the case, the management team will need to revise the objectives and/or consider additional strategic alternatives.

The allocation of resources requires that the list of selected options be prioritised. It is often the case that the availability of specific resources could dictate the priority of an action. Although this is sometimes prudent to do so, the above criteria should be the primary reason for the order of the projects.

## 6.6.7 Formulate strategic plan

Once a set of acceptable strategic options has been selected and the resources allocated, the options should be broken down into **critical tasks** and should the **targets for the key performance drivers finally be set**.

*The definition of critical tasks as well as key performance drivers, the allocation of responsibilities for those tasks and drivers, and the communication thereof is key to the achievement of objectives, and consequently the Mission and Vision of the organisation.*

### 6.6.7.1 Defining critical tasks

The reviewed five categories of critical tasks relevant at the time were as follows:

1.  Create a safe, healthy working environment
2.  Improve competitiveness
3.  Build an effective organisation
4.  Enhance business systems effectiveness
5.  Develop technological capability

To assist in the compilation of the critical tasks, four steps can be followed:

(i)  Identify the **main changes** required to the underlying system and processes in each function area.

(ii)  Determine the **strategic programmes and projects** required to realise these changes.

(iii)  Negotiate **accountability** and **milestones** for strategic actions.

(iv)  Quantify the **impact** of achieving milestones on key financial and key physical indicators.

There are certain important aspects required when compiling critical tasks to promote its regular use. Define each of the following aspects:

●  A **statement** on the task for the previous year with a specific measure such as a target number, date or cost,

●  The achieved **performance** that is updated quarterly,

●  The **targets** for the current year,

●  Three year **milestones** on the subject,

●  A six-year **vision** on the subject.

The process of compiling the critical tasks is iterative and must involve the relevant layers of management and supervision to ensure *a linked hierarchy of critical tasks*, *clear accountabilities* and an *ownership* of the targets set. As the company policy sets the terms of reference for the mine and other operations, so the General Manager's critical tasks provides the collective summary of the critical task sets for the divisional managers, and so on. Where individuals are accountable, the name should be introduced for future reporting.

## 6.6.7.2 Why have both key performance drivers and critical tasks?

**Key performance drivers** are a set of drivers with an economic leverage on the profitability of the company and enables explanation of deviations in the profitability in the company. It provides the focus for daily and monthly performances and is used to *focus, monitor and reward* teams in achieving the objectives of the company. This is done through the use of simple financial models that enable management to evaluate strategic options. It provides for the studying of performance drivers in the context of other drivers and therefore, the quantification of the effect of a driver's impact within the complex interaction with other performance drivers.

**Critical tasks** are the end result of the strategic planning or reviewing process and translate the options into an actionable set of tasks. It is also aimed at supporting a continuous improvement drive. Through these critical tasks the workforce is aligned towards the objectives of the company.

To **summarise** the special relationship between KPDs and Critical Tasks: key performance drivers are developed during the preparatory stage of the planning cycle and hence, have a definite impact on the critical tasks. *If developed properly, all key performance drivers will eventually be included into, or be implied by the critical tasks.* Related as they are, they have somewhat different aims and the one cannot be ignored in favour of the retention of the other.

### 6.6.7.3 Review selection of key performance drivers and set stretching targets

Management may need to revise the performance driver tree and the selection of key performance drivers to reflect the chosen strategic direction. Once the selection of key performance drivers has been finalised, relevant managers should participate in the process of setting targets. These targets should be set in the context of 'world best practice' performance/technical limits and an understanding of the rate at which the business unit can improve.

### 6.6.7.4 The Site Plan

The end result of the planning cycle is the site plan containing the elements shown in table 6.5.

| Table 6.5. Table of contents for Strategic Plan (Adapted from CRA Planning Manual) |
|---|
| **Narrative overview**<br>• Purpose statement<br>• Corporate objectives for stakeholders<br>• Review of performance since last strategic plan<br>• Tables and graphs of historical and projected financial performance<br><br>**Strategic direction**<br>• Overview of industry dynamics<br>• Major opportunities and obstacles<br>• Corporate and Divisional Options Analysis<br>• Top two levels of Critical Tasks Hierarchy: Corporate & Divisional<br><br>**Improvement focus**<br>• Key performance drivers: Divisional waterfall diagrams, Leverage Diagram<br>• Strategic plan targets for key performance drivers<br>• Profit Improvement Projects |

- A **purpose statement** that conveys the main reason for doing business and the measure of success, as well as the means by which the purpose is to be achieved. The purpose statement should address the expectations of all stakeholders.

- The **organisation's long-term objectives** are derived directly from the purpose statement and provide for a detailed wording of the intentions and the measures of success for each objective.

- A **compact analysis of the performance** of the company in comparison with the previous year and the future year's plan should be provided to show the performance trend of the company and to evaluate its relative position in industry. Cash cost breakdowns, wealth created and returns on investment assessments should be key to this part of the site plan.

- The **industry and market situation** should be assessed or summarised from the commercial plan, if available at the time. The drivers of the industry and market should be clearly expressed since they will provide management with sufficient insight to operate within the parameters of the industry. The impact of industry changes on Palabora operations, as shown in Table 6.1, should also be clearly expressed to guide management to optimise on-site wide basis.

- The organisation's **positioning** in its industry should be clearly expressed. This will include statements on the **opportunities and obstacles** that exist e.g. regarding those market segments into which the company wants to expand, in which it wants to maintain its position or from which it wants to withdraw. It should also indicate its strengths and weaknesses and how it intends to position itself with regard to each opportunity and obstacle.

- An **analysis of the options** available to the company and to the divisions is the key section in the site plan. Work done during the preparatory and strategic planning cycle is summarised here and should include all options for each aspect and a short analysis to justify the proposed option(s).

- The **critical tasks for the organisation as a whole and per division** are grouped into the five categories of critical tasks. *Divisional critical tasks*

*should be broken down into Departmental and Sectional tasks with accountabilities and dead lines, the latter only where appropriate.*

- A **waterfall diagram**, which illustrates the improvement potential, and impact on corporate profitability should be shown for each separate division. This section summarises the analysis of the key performance drivers during the preparatory stage of the planning cycle for the *divisions*. A **leverage diagram** for the organisation is required to illustrate the real profit drivers for the *company* i.e. the drivers with the highest potential for improvement **and** the highest leverage on the profit of the company. These diagrams should be among the key inputs in the compilation of the critical tasks. *Key performance drivers that are not reflected in the critical tasks cannot be key drivers.*

- The key performance drivers and critical task development should be translated into a set of **Profit Improvement Projects** that serve as pre-cursors to the eventual capital plan. Profit improvement projects are reported on quarterly and should only include projects that have progressed through the technical and pre-engineering stage. This makes it possible to report on only potentially viable projects and to be able to estimate the impact on the profitability of the company.

### 6.6.7.5 Implementation approach

The General Manager should lead the planning process and appoint a planning team to provide support for the development of the strategic plan. It will usually be appropriate for the Strategic Development Manager to provide the day-to-day management of this team. The role of the planning team will be to coordinate the process, undertake key analyses jointly with relevant managers, involve outside expertise, as appropriate, and assist the General Manager in developing an integrated high quality plan. The Manager Administration should issue a timetable to all participants prior to the start of the strategic planning process. This timetable

should clearly indicate when participants are required to complete preparatory work for workshops.


### 6.6.7.6 Closing the Loop

Strategic planning at the mine has in recent years been performed in the usual single meeting due to the maturity of the company and the stability of the copper markets. The need for this document originated from the fact that Palabora is faced with an increasing amount of change, which is prone to expose any weak aspects in the organisation. It is believed that through rigorous analysis and planning the exposition can be minimised if not negated altogether. *The Focus® model is designed for providing a platform for doing the analysis and is ideal for optimising an incentive bonus scheme to close the management loop.*

Although this section only covered the strategic planning side, the importance of linking the action plans and budgets to the actual strategic plan is imperative for success. Monitoring and actually rewarding teams and individuals for achieving those plans are crucial. To elaborate on these aspects in this document might distract more than add value and hence were excluded.


The crux of the planning process, described in this document, is to involve the different layers of management into a process of learning through which excellence will be acquired. Through this process the *whole* organisation will be focused on value-adding activities and if rewarded on this basis, will generate the dynamism required to face the next twenty-five years and beyond.

# 7 Conclusion

This study was aimed at threading together some of the core disciplines involved in the value chain at any mine site in order to obtain greater insight into how best to extract value for Palabora Mining Company. This activity is not a novel idea, considering the diverse composition of the management teams at mines, and the constant process of integration that takes place anyway in the day-to-day operations. What is novel though, is the approach that was taken in structuring the performance drivers for the company, taking the boundaries of formalized management integration even further. The approach described here ensures that the performance driver structure blends the understanding from the various specialist disciplines into one coherent documented cause-effect model. This combined business-modeling platform allows the multidisciplinary teams to offset costs against benefits for every old or new scenario the organization faces.

The Focus® Model not only allows joint planning around a common planning board but it also leverages this model for corporate performance monitoring. The powerful concept of key performance drivers can easily become yet another activity with limited value if the driver sets are not integrated, or conversely, if the lower order drivers are not derived from common parents. The ability to "drill down" the driver trees towards the specific driver underlying an increasing cost-trend, or a declining production trend, brings clarity and helps resolve problems.

Perhaps one of the greatest benefits of the approach used here is that it is expected of colleagues to clarify and sign off on the fundamentals that drive their business. Now production meetings can become discussions about which play-offs will be the best for the organization as people consider a broader, tested framework where sometimes outdated rules-of-thumb influence decisions.

As pointed out early in the first section, the study focused on the "hard S's" of the McKinsey 7-S model. An attempt has been made in this dissertation to correct for this imbalance by introducing the planning models that largely rest on the CRA

planning models. All the good that came from the study will be of no use if the Focus® model is not designed into the Palabora planning processes. It takes perseverance and serious internal marketing of such a new planning model for it to be absorbed by the organization. The specialist nature of the modeling also requires highly skilled individuals to maintain the mind-share that the approach has in the management echelons of the organization. As such, much more should be done to elevate the use and credibility of this type of integrated planning in organizations. Minerals Resource Management as a discipline certainly offers a nurturing home for the thinking processes described in this document.

It is also hoped that this study will contribute to moving the long-standing boundaries of management and scientific disciplines into a slightly more significant overlap with each other. In the same way value was unlocked when the farm fences that divided gold ore deposits into sub-economic units were taken down, value will certainly be created here. It is guaranteed that when the profit drivers of the various partners in the production chain become visible to each other, the performance of the whole must improve.

# ACKNOWLEDGEMENTS

This he did whilst we were on different continents, and in doing so has surely set an example for perseverance and commitment to a student's plight.

My family deserves the most accolades for accepting my constant absence whilst "dad is busy with that project". Life is about give and take, this time they gave more than I deserved to receive.

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