

## Applying the Theory of Constraints in the South African Coal Supply Chain

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### Abstract

The study explored possible areas for applying the Theory of Constraints in the South African coal mining industry supply chain with the aim of improving effectiveness, efficiency and profitability (throughput). The origin of the Theory of Constraints was explored including various aspects of its application such as the system theory, capacity management, thinking/approach and throughput. Various types of plant classifications were reviewed to ascertain how coal supply chain would be classified. The five step processes pioneered by Goldratt for identifying and alleviating constraints were explored as would be applied in the coal supply chain. The other areas studied included constraint based approach, coal infrastructure, demand management and optimised production technology. The Theory's intended impacts on the coal mining industry supply chain collaboration were also observed.

**Keywords:** Theory of Constraints, coal-supply-chain, throughput, technology, demand

### 1. Introduction

The perspectives of the Theory of Constraints (TOC) were studied with the aim of improving effectiveness, efficiency and profitability (throughput) in the South African coal mining supply chain. TOC was defined by its pioneer Goldratt as a 'holistic understanding of organisational operations, optimising profit (throughput) and maximising utilisation of bottlenecks/constraints in all the processes'. The philosophy is grounded on understanding demand and capacity management for both non-profit and profit-seeking organisations.

The TOC is based on the principle of considering capacity management when products/services flow along a chain of processes. Each process step has a specific capacity to produce output or take input and in every case there is at least one process step that limits throughput for the entire chain which is referred to 'constraint'. Usually there are physical and non-physical constraints. The physical types include processes, personnel and availability of raw materials or suppliers. The non-physical types include procedures, morale, training and others.

The TOC pioneer used the example of a clinician diagnosing the illness of a patient, in explaining the process of identifying and alleviating constraints. The process comprises diagnosis, planning treatment and the execution of the treatment plan. In an organisation, the process involves questioning 'what to change, what to change to and how to cause the change'. Goldratt Institute (2001-2009: 4-7) provided the five-step-process:

- 'Step 1: identify the constraint(s)
- Step 2: develop a plan to overcome identified constraint(s)
- Step 3: focus resources on accomplishing step (2)
- Step 4: reduce the effects of the constraint(s) by off-loading work or by expanding capacity
- Step 5: when one set of constraint(s) is overcome, go back to step (1) and identify new constraint(s)'

These culminated into three guidelines: understanding the process involved in providing product/service; understanding all factors involved in product/service production and overall system operation and ensuring extra support and materials to enable the process to maintain high performance consistently.

As the successful implementation of TOC involves a holistic approach in all types of establishments, it is therefore crucial to understand various operational factors such as systems theory, TOC plant classifications, constraint based approach, capacity management, TOC based supply chain collaboration among others.

### 2. Problem Statement

The problem statement for the study was to establish how the Theory of Constraints would be used to solve constraints found in the South African coal mining industry supply chain in order to improve its operational effectiveness, efficiency

and profitability (throughput).

### **3. The Purpose of the Study**

The purpose of the study was to establish the processes for minimising or alleviating constraints found in the South African coal mining industry supply chain using the Theory of Constraints. These are constraints established at all the stages of the supply chain commencing with the mining process, transportation and coal processing for energy and petrochemicals.

### **4. Methodology**

The study adopted a qualitative research paradigm. According to Cooper and Schindler (2008: 162-168) the outcome of the qualitative interview depends very much on how the researcher prepares the participants for the interview. 'Qualitative research has substance, gives insight, shows sensitivity and is unique in conceptualisation, yet grounded in data' (Corbin & Strauss 2008: 302).

Various aspects covered by this study included selection of participants, undertaking the interview, feedback on the interview for validity/reliability and facilitating data collection in a recorded form using an audio data recorder and field notes. Citing Goddard and Melville (2005: 49) the researcher must not direct the participant's answer through his tone of voice or rephrase the research question. Research design involves activities of 'collecting and analysing data, developing and modifying theory, elaborating or refocusing the research questions, identifying and addressing validity threat' (Maxwell 2005: 2).

The selection and profile of the participants was done using purposive sampling process. The process aimed to enhance understanding of the selected people and groups as they were selected for a specific purpose, task or expertise in research. 'The researcher should be in a position to expound the use of purposive sampling in order to instill confidence and validity for research findings' (Devers & Frankel 2000: 264-265). The participants for this study were the top professionals who were also involved in decision making in their respective organisations in order to provide credibility to the study. There were 14 respondents earmarked for this research and 13 of them responded: 12 respondents were interviewed at their work place while 1 respondent provided a telephonic interview. The interview population of the 13 respondents comprised 4 Chief Executives and 9 senior professionals in the mining and affiliated industries nominated by their respective chief executives.

#### **4.1 Sample and Procedures**

The researcher is required to obtain permission from gate-keepers of the target institutions in order to obtain access to individuals and institutions (Ehigie & Ehigie 2005: 622-623). The permission to conduct research either oral or written is paramount (Cooper & Schindler 2008: 37). The objectives for the research were addressed at the initiation stage as the researcher approached the institutions' gate-keepers by stipulating the value proposition for the study, purpose and ethical considerations that also addressed the 'informed consent' (admissibility for research process).

Some of the critical requirements for a researcher are skills in negotiation and relationship building to be able to successfully access the prospective respondents. In this study, the researcher approached the selected participants via telephone and e-mail and briefed them on the value proposition for the project. Since the respondents were senior executives in their respective companies, some of them responded directly, while the others responded through their personal assistants. In two occasions the researcher was invited to give a presentation on the purpose of the research before the consent to interview was granted. A research introduction letter from the Vaal University of Technology formed part of the presentation. The content of the letter included the introduction of the researcher, confidentiality undertakings and the use of audio digital data recorder for recording the interviews.

#### **4.2 Data Analysis**

The use of the audio digital data recorder and the field notes were the methods used for data collection. The collected data was transcribed and content analysis was used for the translation and analysis. The emerging themes and sub-themes were recorded and evaluated to establish constraints that exist in the industry that would be resolved by the public-private partnership model.

#### 4.3 Reliability and Validity (Measures of Trustworthiness)

Triangulation method was used to check the reliability and validity of data from this study. The process involved were comparing data from the interviews, feedback from the participants and from the literature. The researcher's field notes articulated the respondents' output. Some participants also provided written clarifications of some of their contributions after the interview. 'Multiple sources lead to a better understanding of the phenomena being studied' (Willis 2007: 219). Triangulation enhances validity and richness of data by looking at issues from different angles (Lee & Lings 2008: 239).

#### 4.4 Ethical Procedures

According to Eriksson and Kovalainen (2008: 68) research is vulnerable to 'lies, fraud and wrong-doing' hence, ethical adherence is paramount. The ethical issues for this study were addressed through the research introduction letter from the Vaal University of Technology addressed to those participants who had accepted the invitation for the interview. The letter provided confidentiality, anonymity and use of pseudonyms between the respondent and the researcher.

### 5. Results

**Table 1:** Themes and sub-themes emanating from the interviews

Themes	Sub-Themes
Coal: origin, quality, business model, production, consumption and trade (economic benefits/welfare of employees and communities)	<ul style="list-style-type: none"> <li>- Coal and its properties, reserves, production, consumption and trade</li> <li>- Employee satisfaction</li> <li>- Community welfare</li> <li>- Environmental impact</li> </ul>
Legislative environment (MPRDA, NEMA, NERSA)	<ul style="list-style-type: none"> <li>- MPRDA Act of 2002</li> <li>- NEMA Act of 1998</li> <li>- NERSA</li> </ul>
Role players: coal mines (private), Transnet- rail (public), Chamber of mines (private)	<ul style="list-style-type: none"> <li>- Coal-mines</li> <li>- Transnet (rail transport)</li> <li>- Chamber of mines (advisory roles)</li> </ul>
Transport infrastructures: conveyor belts, rail, road, water. Road damage in power stations area of Mpumalanga Province	<ul style="list-style-type: none"> <li>- Rail for export coal and less for domestic transport</li> <li>- Road damages in power station areas</li> <li>- Conveyor belts for collieries tied to power stations</li> </ul>
Ownership of the rail/TFR-TRANSNET	<ul style="list-style-type: none"> <li>- State ownership of rail hinders maximum collaboration</li> </ul>
Skills shortage across the industry	<ul style="list-style-type: none"> <li>- Mining engineers, managers, artisans, mining equipment, rolling stock, trains, old rail gauge</li> </ul>
Environmental issues: pursuing green initiative, social responsibility. Commitment to "cradle to grave" philosophy of green environment Dilapidated coal mines in Mpumalanga Province	<ul style="list-style-type: none"> <li>- Environmental degradation: carbon emissions, dust, noise and diesel pollution</li> <li>- Coal transport by road</li> <li>- "cradle to cradle" and "cradle to grave", product reuse, recycle rehabilitation (soil, water, mines)</li> </ul>

**Source:** Mathu (2011: 222-223)

Table 1 indicates the themes and sub-themes that emanated from the study. The themes focus on the history and properties of coal; legislative environment; coal supply chain role players; transport infrastructures; rail ownership, skills shortage and environmental impacts. These are the areas where constraints in the coal supply chain occur.

### 6. Discussion

The major themes that emerged from the interviews with the respondents were actually the seven major constraints experienced in the South African coal mining industry supply chain. The constraints covered a wide range of issues including coal and its properties; legislative environment; industry role players (government, public and private enterprises); transport infrastructure, ownership of Transnet Freight Rail (Transnet); skills shortage and environmental issues. The possible application of the Theory of Constraints (TOC) to alleviate or minimise the constraints experienced is articulated herewith:

### 6.1 Coal and Its Properties

Coal is a fossil fuel and a primary source of energy in South Africa. Coal is formed from accumulation of dead vegetation over many years, undergoing a slow decaying process turning into peat that transforms into coal seams (Anglo Coal 2007: 47). According to Abbott, Apostolic, Goodman, Hortsman, Jenner, Jewell, Labhart, Maragos, May, Sunderman, Parke, Stein, Wengler and Went (2009: 53) the slow formation process that takes millions of years make coal a nonrenewable source of energy.

South African coal is associated with the Karoo rock formations which extend over the present day Free State, Mpumalanga, Limpopo and Western Natal. The chemical composition and properties of coal determine its usage. South African coal is less reactive, harder and has lower sulphur content compared to coal from the Northern hemisphere. The bulk of South African coal is bituminous or thermal grade suitable as fuel for electricity generation and anthracite suitable for metallurgical plants (Lang 1995: 20).

Carbon contents determine the calorific value (heat value) and it is used in the classification of coal (Abbott *et al.*, 2009: 53) viz:

1. Lignite Coal: It is the lowest ranked coal with carbon content of 25-35% and it is mainly used in power stations to generate electricity.
2. Sub-bituminous Coal: It has higher calorific value than lignite, contains 35-45% carbon and its main use is also as fodder for the power stations.
3. Bituminous Coal: It has higher calorific value than sub-bituminous, contains 45-86% carbon and it is used for power generation and in the metallurgy industry as 'coke' for the production of iron and steel.
4. Anthracite Coal: It is the highest ranked coal in quality and it is hard, glossy and black. It possesses the highest calorific value, contains 86-97% carbon and it is mainly used for residential and commercial space heating.
5. Graphite Coal: It possesses the same quality with anthracite and it is mainly used in pencil making and as a lubricant when powdered.

### 6.2 South African Coal Reserves

South Africa has coal reserves of approximately 30 408 million tons, the sixth largest coal reserves in the world. The coal reserves are found in Mpumalanga, Free State, Limpopo, Kwa-Zulu Natal and Limpopo coalfields (DMR 2009:44).

The South African coalfields are mainly concentrated in the Mpumalanga coalfields where most of the coal-fired power plants are situated. The 650 kilometres rail line that transports coal to the Richards Bay Coal Terminal for export also runs from this area. Mpumalanga Province presently produces in excess of 70 percent of the South African coal, but the reserves are currently running low (depleting). It is estimated that from around 2020, coal mines in the Mpumalanga area will start relocating to the Waterberg coalfields in Limpopo Province which has abundant, untapped coal reserves (Chamber of Mines 2009:27).

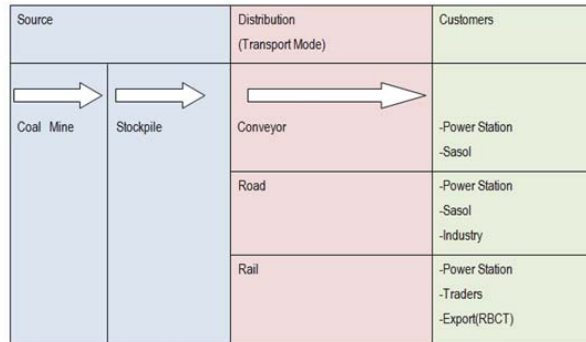
There are 73 collieries in South Africa (Prevost 2009: 27). Most of them are owned by the five leading mining companies that produce over 80 percent of coal in the country and the others are owned by smaller black economic empowerment (BEE) mining companies or junior miners that contribute the remaining 20%. The national distribution of the collieries comprises: Free State (2); Gauteng (1); Kwazulu-Natal (7), Limpopo (2) and Mpumalanga (61).

### 6.3 South African Coal Mining Business model

There are two types of business models for coal mining in South Africa namely domestic and export models. The domestic model has three stages which comprises the mining process, transportation to the domestic customers/consumers and the processes at the customers' facilities who are usually the consumers. The export coal model also has three stages which are mining process, transportation to the coal export terminal by rail and shipping to overseas customers by sea. The export terminal is at Richards Bay along the Indian ocean coast of Kwa-Zulu Natal.

The following figure shows the South African coal mining business model depicting both domestic and export markets.

**Figure 1:** The South African Coal Mining Business Model for Domestic and Export Markets



**Source:** Mathu 2011: 63

The South African coal mining business model has three main stages: source (coal mining/ beneficiation), transportation (mode of transport used) and customers/ consumers.

### 6.3.1 Stage 1: Mining

The mining process involves removal of overburden on the top of the mine and coal that is brought to the surface mixed with rocks. The rocks are sorted from coal and delivered to a dump site. Coal free of rocks is stockpiled on a site allocated near the mine.

### 6.3.2 Stage 2: Distribution (Transportation)

Three types of transport modes are used for local distribution to the customers conveyor, rail and road while rail and ship are used for export. The power station coal is delivered direct from the stockpiles and does not go through the beneficiation process. The bulk of the power station coal is delivered via conveyor belts. The rest is delivered by road and rail. The export coal is taken through the beneficiation process and delivered to the export terminal by rail. The coking coal for metallurgical industry, cement industry, aluminium smelters and for the traders is delivered by road and rail.

### 6.3.3 Stage 3: Customers

The domestic customers for coal are the power stations, Sasol, industry and traders while the export customers abroad are the power stations and industry.

### 6.3.4 Coal Logistics

Logistics complements supply chain through strategy, design and execution. Supply chain design entails strategic functions involving the chain members, its length, breadth, locations systems and relations (Waters 2007: 42). The holistic logistics functions as in the coal supply chain comprises: procurement and purchasing; inward transport (inbound logistics); receiving; stockpiling; stock control; material handling; outward transport (outbound logistics); reverse logistics and communication (coordinating flow of information and money).

Purchasing is a very important logistics role and Porter (1985: 39:40) stated its five pillars which include inbound logistics, outbound logistics, operations, marketing/sales and services. These pillars are also applicable in the coal logistics.

The transport role in coal logistics includes product movement (coal), stockpiling, inbound logistics (supplies to the mining company), outbound logistics (coal deliveries to customers/consumers), Third-Party logistics (3PL) (outsourced transport transporting coal to customers/consumers) and Fourth-Party logistics (4PL) (outsourced management services such as (IT) (Waters 2007: 71).

The broad application of these logistics functions constitutes their implications in the coal supply chain.

## 7. Theory of Constraints Applications

The approach to constraints minimisation and alleviation in the South African coal supply chain is elaborated at all the crucial stages. The process would involve changes and use of new technologies and training in order to improve throughput.

### 7.1 The Relevance of Systems Theory

It refers to the extent to which standard procedures are made explicit. To create goods/services, organisations perform three functions namely marketing, production/operations and finance/accounting (Heizer & Render 2008: 4).

Marketing: generates the demand and takes order for a product/service (sales).

Production/operations: creates the product/service.

Finance/accounting: tracks how well an organisation does in paying bills to suppliers (accounts payable) and collects money from the clients (accounts receivable).

In any production/operations, there are bottlenecks that constrain throughput. Throughput is the rate at which the system generates money through sales (Finch 2008: 663).

### 7.2 Theory of Constraints Plant Classifications

Lepore and Cohen (1999: 43-57) identified four types of TOC plant classifications as: I-plant, A-plant, V-plant and T-plant.

I-plant (one-to-one): where materials flow in sequence of events one-to-one as in assembly line. The constraint here is in the slowest operation.

A-plant (many-to-one): happens where many assembly lines converge for a final assembly. The constraint here is in synchronisation of the converging lines so that each supplies the final assembly at the right time.

V-plant (one-to-many): where one raw material produces many final products. The constraint happens at the time of diverging from one product to the other, a process referred to as 'robbing' or 'stealing'.

T-plant (many-to-many): plants that have multiple lines which then split into many assemblies. Both A-plant and V-plant are experienced at this type of plant.

Therefore, in TOC plant classification, coal mining falls under V-plant (one-to-many) as coal is a source of energy in more than one form and other applications such as petrochemicals production. According to Jiang, Zhou and Meng (2007: 6), constraints in the coal mining industry are both internal and external. Internal constraints refer to operational, logistics, systems, skills and staff morale. External constraints are experienced in transport logistics, marketing, stockpiles, collaborations, legislations, weather and environment.

### 7.3 Demand Management

Successful demand management involves coordination of marketing and operations departments focusing on pricing, promotions, reservations and waiting period (Barnes 2008: 151).

In the South African coal supply chain long-term plan of coal supply to customers such as the power stations is used. The long-term plan is based on present and anticipated future demands for coal. The price for the coal supply contract is agreed at the time of signing the contract. Presently, the leading producer of electricity in the country Eskom has problems with old coal supply contracts as the cost of electricity generation has risen beyond the original prices agreed at the signing of contracts with some of the major suppliers. The reason for the price disparity is mainly inflation caused by global economic disruptions. This is a serious constraint that needs to be addressed urgently so that power cost to consumers could be stabilised.

### 7.4 Capacity Management and Throughput Across the South African Coal Supply Chain

The objectives of coal supply chain management are to meet customer needs in product/service quality and quantity. This encompasses the processes of resource exploration, prospecting, exploitation (mining), beneficiation and transportation. Jiang, Zhou and Meng (2007: 6) attributes constraints in the coal supply chain to issues such as:

- most companies' failure to implement supply chain concept;
- most coal companies are profit driven and overlook the cooperation and information-sharing with members of the value chain;

- lack of proper training in supply chain for employees and
- constraints are usually experienced in transportation and resources.

### 7.5 Constraints-based Approach

Constraints-based approach is defined as a way of realising productive change to correct the negative impact of the constraint(s) on supply chain profitability. This is either by the lead member of the supply chain providing a reliable measurement of progress of revenue generation by the supply chain or by focusing on the supply chain performance improvements. In the 'make-to-store' supply chain, the constraint is often with the end customers who visit the store to buy the product (Lepore & Cohen 1999: 43-57). This is analogous to the coal-mining industry where the situation is 'mine-to-stockpile' before the shipment of coal to both domestic and export customers.

### 7.6 Infrastructural Constraints

The coal transportation in South Africa is done by conveyor belts, rail, road and water (DME 2009: 39). Presently, internet has become a necessity in enhancing communication, integration and collaboration between the channel partners. Infrastructural constraints are experienced where road transport is used, limited rail capacity due to rolling stock shortage, harbour capacity, old gauge and skills shortage.

The conveyor belts are very convenient and used at power stations which were built next to designated coal mines for the ease of transportation cost. Most of these power stations are situated in the Mpumalanga coalfields which are now experiencing depletion constraint. The reduced production capacity of the designated mines has led to the power stations receiving additional capacity from other distant coal mines via road transport. This results to environmental constraint through extensive road damage, air/noise pollution and accidents.

South African rail is still of the old gauge limited only to the local usage. The increased energy demand in the last decade required more coal imports from coal producing countries such as South Africa. In order cope with the huge demand, the leading coal handling harbour Richards Bay Coal Terminal (RBCT) continued to expand its capacity, but the feeder rail remained constant for many years. RBCT is privately owned by the leading coal mining companies which produce over 80% of coal in the country. The harbour reached 91mtpa in 2010 and there are plans to increase the capacity to 110mtpa (Kolver 2014: 1). RBCT is connected to the coal mines via Transnet Freight rail (TFR), a distance of 650km running from Mpumalanga coalfields to Richards Bay coal terminal along the Indian ocean. It is also the biggest coal terminal in the world (Transnet 2013: 86). The terminal coordinates with the Transnet National Ports Authority (TNPA) for the arrival and departure of more than 700 ships per annum (Coal International 2007: 12).

The rail network is run by the government through the state corporation Transnet, Transnet uses its business unit Transnet Freight Rail (TFR) to run the rail system in the country. The rail export coal transportation capacity is 81mtpa which is still below the harbour handling capacity. These capacity disparities are constraints that need addressing urgently to improve throughput in the export coal market.

### 7.7 Optimised Production Technology (OPT)

Optimised Production Technology (OPT) is a software system that is specifically used for production scheduling and has adapted the TOC initiative in application. Hence, OPT/TOC has become a production planning and control (PPC) method which attempts to optimise scheduling by maximising the utilisation of the bottlenecks in the process (Davis & Heineke 2005: 618).

The integrated PPC has three major approaches namely push systems, pull systems and bottleneck systems. The bottleneck systems/constraints apply to the case in which a stage or a number of stages in a system cannot process the goods or services quickly enough to prevent backlog in terms of work-in-process (WIP) and demand (Davis & Heineke 2005: 619).

### 7.8 Applying Theory of Constraints to Supply Chain Collaboration

The Theory of Constraints in the supply chains looks at the issues of supply chain connectivity and collaboration within the value chain. A holistic evaluation of the value chain constraints in logistics, operations, warehousing, performance measures and profitability are conducted.

Supply chain collaboration is defined as two or more independent firms jointly working to align their supply chain

processes so as to create value to their customers and stakeholders with greater success than acting alone. Collaborating firms share responsibilities and benefits by establishing a degree of cooperation with their upstream and downstream partners in order to create a competitive advantage. The TOC application comprises sets of three interrelated areas: logistics, performance measurements and logical thinking. In collaboration, individual firms control approximately 20% and the other 80% is under the supply chain. The joint decision-making succeeds in creating competitive advantage through collaboration in market access, better material sources and cost-effective transportation (Simatupang, Wright & Sridharan 2004: 57-58).

A holistic process of supply chain collaboration involves a five-step thinking process which includes plan, check, categorise, metrics and control (Ruston, Coucher & Baker 2006: 215-217). These are the type of changes that require implementation in the coal supply chain. The South African scenario is complicated because the crucial rail logistics player is the government whose policies frustrate means of coordination towards collaboration with the mining sector which is private.

## **8. Legislative Environment**

This study concentrated on the legislative environment from the South Africa's Department of Mineral Resources, Department of Water and Environmental Affairs and the National Energy Regulator of South Africa.

- a) Department of Mineral Resources (DMR)  
The Department of Mineral Resources (DMR), previously Department of Minerals and Energy (DME), uses the Mineral and Petroleum Resources Development Act (MPRDA) – Act 2002 (Act No. 28 of 2002) that was promulgated in April 2004 in the administration of the mining industry (Government Gazette 2006: 3).
- b) Department of Water and Environmental Affairs (DW&EA)  
The Department of water and environmental affairs (DW & EA) ensures that mines has environmental management plan (EMP) based on the principle of integrated environmental management as provided by the National Environmental Management Act (Act No. 107 of 1998) NEMA (Government Gazette 2010: 3).
- c) National Energy Regulator of South Africa (NERSA)  
The National Energy Regulator was established under Section 3 of the National Energy Regulator Act, 2004 (Act No. 4 of 2004), NERSA's mandate is to maintain a delicate balance between the regulated energy industries, users and consumers (NERSA 2008:16). The regulatory body advises the electricity and other energy institutions on the tariffs they charge the consumers and arbitrates grievances between the consumers and the energy distributors, among other roles. This ensures that the end users and consumers receive appropriate service and pay the correct rates recommended by the government (NERSA 2009:11-15).

### **8.1 Chamber of Mines of South Africa**

The Chamber of Mines of South Africa is a voluntary membership private organisation which was founded in 1889 to look into the affairs of the mining industry. The Chamber liaises with universities and international organisations for mining related research and bridges between the government, labour unions and the mining industry (Chamber of Mines 2009: i).

## **9. Skills Shortage (Constraints)**

The need for more coal-fired power stations and new coal mines calls for more skills in technical areas in the supply chain that includes engineering, transportation and equipment operations. According to Wilhelm (2009: 6) estimates, building 40 power stations would require 600 engineers and 2 500 artisans.

## **10. Environmental Impacts (Constraints)**

All the participants reaffirmed a continuous liability in managing 'green' issues as required by the mining legislation and the willingness of their respective organisations to respond to the requirements. The legislation would ensure control of the dilapidated ownerless coal mines, continuous burning of coal mine dumps, air and water pollution.

The power generation from coal consumes approximately 50% of the total coal mined in South Africa and the production of synthetic liquid-fuels and petrochemicals consumes 18%. These energy producing processes are the leading carbon emitters in the country and hope to employ more effective measures in future to control the emissions



(Lloyd 2002: 47).

It is estimated that by 2020 South Africa will increase coal production by 75mtpa and production of clean energy from renewable sources and nuclear would increase tremendously according to the 2010 Department of Energy's integrate resource planning (IRP2). The country has a target of reducing of reducing carbon emissions by 34% from a business-as-usual scenario in 2020 and 42% in 2025 (Salgado 2010b: 19).

According to a phenomenon called 'Lloyd's Blanket Atmospheric Pollution', a European satellite image above Mpumalanga and Gauteng Provinces indicate a high level of nitrogen dioxide atmospheric pollution due to coal-based electricity generation in the region (Abbott et al. 2009: 87). The future energy generation and consumption from coal sources will require technologies which would control carbon emissions and sustainable modes of transport on land (Resource 2010: 16).

Presently, more than three-quarters of South African carbon emissions come from energy generation and consumption. Therefore, increased energy mix will reduce coal use drastically in order to realize the anticipated target for 2020 and 2025. 'The current coal-fired power stations will be decommissioned by 2025 when their economic life expires. However, the new coal-fired-power stations that will come on stream in future including the two new ones under construction Medupi and Kusile, will use clean coal technology (CCT)' (Eskom 2011: 59).

The respondents concurred that the environmental degradation by excessive use of transportation of coal by road would be controlled by building additional rail lines linking the coal mines with the power stations in future. The extensive use of rail transport would also reduce noise and air pollution.

The philosophies of 'cradle to cradle' and 'cradle to grave' according to the respondents, means that companies should manage their products' life cycle in both forward (towards point of sale) and backward (reverse logistics) movements in the supply chain.

## **11. Limitation of the Study**

The study being qualitative had a limitation on the number of participants. A total of 13 professionals from the coal mining industry and the role players were interviewed. Recruiting such high caliber professionals was time-consuming in accessing them and their institutions as explained in the methodology chapter. However, the response by the respondents from the industry was positive (13 approvals out of 14 proposals).

Accessing the industry had other limitations due to its nature as energy industry and energy is a sensitive subject because of its critical role in sustainable development. The institutions in the industry are not easily accessible without convincing reasons and introducing a research topic is not one of the most desired reasons to gain access. However, with skills and patience, it was possible to gain access and to successfully accomplish the project.

## **12. Conclusion**

The constraints in the South African coal mining industry supply chain are experienced in all stages of the value chain. The coal mining industry was introduced and vulnerable areas for constraints exposed. The inputs from the interview participants highlighted the constraints areas and suggestions were provided for possible introduction of Theory of Constraints principles to minimise or alleviate the constraints in the supply chain. The lack of integration and collaboration by the role players who are both public and private sectors were discussed.

## **13. Recommendations**

This study recommends implementation of a public-private partnership (PPP) model for the South African coal mining supply chain citing current inadequate logistics integration and collaboration between the state owned rail company Transnet and the privately owned coal mining industry. A PPP model would minimise or alleviate constraints experienced in the coal supply chain and improve operational efficiency and effectiveness that would in turn improve profitability (throughput). The focus would be on general operational issues and policy implementations.

### **13.1 General recommendations:**

- The coal mining industry needs to move from internal focus to cross-enterprise collaborations. Such collaborations would enable industry players to look beyond the profit focus and start seeing the value of cooperation and information sharing with the other members of the value chain.

- An Integrated strategy on the development of the coal mining industry (ISDCM) need to be developed to facilitate communication among the role players in the coal mining industry.
- The industry should have long-term plans for skills development to address the skills deficiencies in the industry at all times.
- There should be a shift from road to rail for coal transportation to limit the environmental degradation by trucks.

### 13.2 Policy recommendations

At a policy level the study recommends that the coal mining industry develops an Integrated Strategy on the Development of Coal Mining (ISDCM) for South Africa. The critical elements of the strategy should be:

- a policy legislative environment;
- working towards a common and shared vision in the industry;
- developing rail and infrastructure;
- developing skills;
- attracting new investors in the industry;
- diversifying ownership of the rail and Transnet; and
- managing the environment.

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