SUPPLY CHAIN CONSTRAINTS IN THE SOUTH AFRICAN COAL MINING INDUSTRY

by

KENNETH M MATHU
STUDENT NUMBER: 208059822

Thesis submitted in fulfilment of the requirements for the Degree: Doctoris Technologiae (Business) in the Faculty of Management Sciences, Vaal University of Technology.

Promoter: Dr. David Pooe
Co-promoter: Prof. Andrea Garnett

November 2010

ABSTRACT

The study explored the South African coal mining industry and it's role players to establish the causes of the bottlenecks/constraints experienced in the coal mining industry supply chain. A qualitative research paradigm methodology was used. Both theoretical and philosophical assumptions were utilised with inferences from and references to works by other researchers to broaden the knowledge horizons for the study. Thirteen supply chain executives and professionals from the key role players in the coal mining industry were interviewed and provided invaluable input for the study.

The study determined the presence of communication barriers between the industry role players in the public and private institutions that culminated in main themes and sub-themes being established from which the industry constraints were uncovered. The study identified six main constraints affecting the various role players within the coal mining supply chain and it culminated in the model that would enable the industry to minimise such constraints. To this end, the study proposes the development of an Integrated Strategy for the Development of Coal Mining (ISDCM).The model is based on the public and private partnership arrangement that would alleviate most of the prevailing constraints when implemented. The model would furthermore have the capacity to rectify most of the existing constraints. It would be funded from the commercial sector and would operate on triple bottom lines of economic, social and environmental factors, with equal weight. This is a desirable direction for the future in order to maintain sustainable development.

Emanating from the study are policy and research recommendations for the South African coal mining industry, covering the coordination of the critical areas of the proposed integrated strategy for the development of the coal mining industry. Such recommendations include further research into new coal mines and power stations as well as perceptions and expectations of potential investors in the industry, among others.

DECLARATION

I Kenneth M Mathu hereby declare that this project is my original work and contains no material or work previously written or published by any other individual and to the best of my knowledge, it has not been used as the basis of degree or diploma awards at a University or at any other institution of higher learning, except for the references acknowledged in the text.

KENNETH M MATHU

ACKNOWLEDGEMENT

I would like to take this unique opportunity to express my deep gratitude to the following individuals/institutions/entities that I hereby acknowledge as having been instrumental in bringing this project to fruition:

- God for grace and talent bestowed upon me;
- The Vaal University of Technology for providing me with the opportunity to carry out this project;
- Dr. David Pooe, my senior Promoter at VUT for his indefatigable, selfless mentoring, supervision and guidance through this tortuous academic journey;
- Prof. Andrea Garnett, co-promoter at the VUT for her witty professional guidance;
- All the participants for their invaluable time and interview contributions that were instrumental in the success of this project; and
- Gratitude to my family and friends for their support.

TABLE OF CONTENT

PAGE

CHAPTER 1

INTRODUCTION AND BACKGROUND TO THE STUDY

CHAPTER 2

THE SOUTH AFRICAN COAL MINING INDUSTRY

CHAPTER 3

COAL MINING AND THE ENVIRONMENT

CHAPTER 4

SUPPLY-CHAIN AND LOGISTICS MANAGEMENT

CHAPTER 5

THEORY OF CONSTRAINTS

CHAPTER 6

RESEARCH METHODOLOGY

CHAPTER 7

DATA PRESENTATION, ANALYSIS AND INTERPRETATION

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

LIST OF FIGURES

LIST OF GRAPHS

LIST OF MAPS

LIST OF TABLES

ACRONYMS

3M	Minnesota Mining and Manufacturing
3PL	Third-Party Logistics
4PL	Fourth-Party Logistics
AATP	Allocated Available To Promise
AMD	Acid Mine Drainage
APS	Advanced Planning and Scheduling
ARA	Amsterdam-Rotterdam-Antwerp
AsgiSA	Accelerated and Shared Growth Initiative for South Africa
AS/RS	Automated Storage and Retrieval System
B2B	Business to Business
B2C	Business to Consumer
BC	Before Christ
BEE	Black Economic Empowerment
BP	British Petroleum
BPO	Business Process Outsourcing
BPR	Business Process Re-engineering
BRTT	Below Rail Transit Time
C & F	Cost and Freight
CAGR	Compounded Annual Growth Rate
CAIA	Chemical and Allied Industries Association
CCT	Clean Coal Technologies
CE	Chief Executive
CEC	Caption Exchange Capacity
CEO	Chief Executive Officer
CIF	Cost Insurance and Freight
CIP	Carriage and Insurance Paid
CITT	Coal Industry Task Team
CLM	Council of Logistics Management
CMI	Co-Managed Inventory

CPT	Carriage Paid To
CRC	Centralised Return Centre
CRIMP	Coal Rail Infrastructure Master Plan
CRM	Consumer Relationship Management
CSCMP	Council of Supply Chain Management Professionals
CSEC	China Shenshua Energy Company
CTL	Coal-To-Liquid
CV	Calorific Value
CWS	Coal-Water Slurry
DAF	Deliver At Frontier
DCM	Demand Chain Management
DCs	Distribution Centres
DCT	Durban Coal Terminal
DDP	Delivered Duty Paid
DDU	Delivered Duty Unpaid
DE	Department of Energy
DEAT	Department of Environmental Affairs and Tourism
DEQ	Delivered Ex-Quay
DES	Delivered Ex-Ship
DME	Department of Minerals and Energy
DMR	Department of Mineral Resources
DoT	Department of Transport
DSL	Digital Subscriber Line
ECR	Effective Consumer Response
EDI	Electronic Data Interchange
EEC	European Economic Community
EAI	Energy Information Agency
EMS	Event Management Systems
EOQ	Economic Order Quantity
EPOS	Electronic Point Of Sale

ERP	Enterprise Resource Planning
ESKOM	Electricity Supply Company of South Africa
EU-ETS	European Union-Emission Trading Scheme
FAS	Free Alongside Ship
FC	Fixed Carbon/Fixed Cost
FGD	Fluidised Gas De-nitrification
FMCG	Fast-Moving Consumer Goods
FOB	Free On Board
FOR	Free On Rail
FTL	Full Truck-Load
GARP	Global Association of Risk Professionals
GDP	Gross Domestic Product
GTL	Gas-To-Liquid
IATS	Integrated Asset Tracking System
ICE	Intercontinental Coal Exchange
ICT	Information Communication Technology
IDC	Industrial Development Corporation
IDI	Individual Depth Interview
IEA	International Energy Agency
IGCC	Integrated Gas Combined Cycle
IMS	Inventory Management System
ISO	International Standardisation Organisation
IT	Information Technology
JIT	Just-In-Time
JSE	Johannesburg Stock Exchange
kWh	Kilowatt hour
LOM	Live- Of- Mine
LTL	Less Than Truck-Load
MCT	Matola Coal Terminal
MPRDA	Mineral and Petroleum Resources Development Act

MPS	Master Planning Schedule
MRP	Material Resources Planning
MRP2	Manufacturing Resources Planning
Mt	Million tons
Mtpa	Million tons per annum
MW	Mega Watt
MWh	Mega Watt hour
NEMA	National Environmental Management Act
NERSA	National Energy Regulator of South Africa
NOC	National Operations Centre
NPC	National Planning Commission
NRC	National Research Council
O & G	Oil and Gas
OE	Operations Expenses
OM	Operations Management
OPT	Optimised Production Technology
PED	Primary Energy Division (ESKOM)
POS	Point Of Sale
PPC	Production Planning Control
PPP	Public and Private Partnership
R & D	Research and Development
RBCT	Richards Bay Coal Terminal
RFID	Radio Frequency Identification
ROI	Return On Investment
ROM	Return-Of-Mine
ROW	Rest Of World
SA	South Africa
SAMI	South Africa’s Mineral Industry
SASOL	South African Oil Company
SC	Supply Chain

SCC	Supply Chain Collaboration
SCM	Supply Chain Management
SCOR	Supply Chain Organisation Reference
SCP	Supply Chain Planning
SFA	Sales Force Automation
SOM	Soil Organic Matter
SWOT	Strengths, Weaknesses, Opportunities and Threats
TFR	TRANSNET Freight Rail
TMS	Transport Management System
TNPA	TRANSNET Ports Authority
TOC	Theory Of Constraints
TPS	Transportation Planning System
TPT	TRANSNET Ports Terminal
TQM	Total Quality Management
TW	Terra Watts (million watts)
UNFCCC	United Nations Framework Convention on Climate Change (Kyoto Protocol, 1997and Copenhagen Accord, 2009)
US	United States
USA	United States of America
USD	United States Dollar
UK	United Kingdom
VAT	Value Added Tax
VM	Volatile Matters
VMI	Vendor-Managed Inventory
WCI	World Coal Institute
WEBC	Western Basin Environmental Corporation
WEC	World Energy Council
WIP	Work-In-Progress
WMS	Warehouse Management Systems

CHAPTER 1
INTRODUCTION AND BACKGROUND TO THE STUDY

1.1 INTRODUCTION

The aim of this study was to explore the supply-chain constraints facing the South African coal-mining industry supply chain with a view to developing a model which would assist in minimising such constraints.

This study has examined the coal supply-chain constraints from the commencement point (at the mine) through to the transportation of coal to customers (domestic and export). The domestic coal-supply chain entails local coal consumption for power generation, petrochemical production in the metallurgical and general industries. The export coal-supply chain is entirely for coal exported to other countries. The three steps of the domestic coal supply-chain (mine, transportation and customers) and two steps for export coal supply-chain (mine and transportation to coal export terminals) form the basis of this study.

The domestic coal supply chain is dominated by coal supply from the mines to the power plants for electricity generation. The transportation modes used include conveyor belts, road and rail. The domestic coal-supply chain includes the industries and the traders while the export coal-supply chain starts from the mines through the coal export terminals via the rail system where it is loaded onto ships for transportation overseas.

Supply-chain constraints entail capacity management when products or services flow along a chain of processes. The theory of constraints (TOC) developed by Goldratt in 1990 provides the philosophy for constraints management (Goldratt 2001-2009:9). The TOC is based on the recognition that nearly all products and services are created through a series of linked processes (Bozarth & Handfield 2006:222).

Davis and Heineke (2005:104) define supply-chain management as the long-term relationship between a firm, its suppliers and customers in order to ensure the timely delivery of the goods and services that are competitively priced. Logistics forms a vital part of supply-chain management. Transport functionality provides two major services: movement and product storage. The primary value proposition of transportation is product movement and storage while the transportation is in transit through the supply chain (Bowersox, Closs & Cooper 2007:167).

According to Pycraft, Singh, Phihlela, Slack, Chambers, Harland, Harrison and Johnson (2003:475), supply-chain management is about managing the entire chain of raw material supply, manufacture, assembly and distribution to the customer while Quayle and Jones (1999:4) define supply chain as an integrative philosophy to manage the total flow of a distribution channel from the supplier to the ultimate user.

The supply chain encompasses both the demand and the supply sides of the business operation. On the one hand, the demand side involves managing physical distribution of goods downstream to service the first and second tiers of customers while on the other hand, the supply side involves managing functions of purchasing and supplies through the first and second tiers of suppliers (Pycraft *et al.* 2003:459). Through integration, transactions, facilitations and information both suppliers and customers build a web of relationships within and between chains (Boyson, Harrington & Corsi 2004:89).

The information flow is enhanced by systems such as electronic data exchange (EDI), materials resource planning system (MRP), optimised production technology (OPT), electronic point of sale (EPOS), radio frequency identification (RFID), the internet/intranet and others (Rushton, Croucher & Baker 2006: 530-540). Essentially, the goal of supply-chain management is cost reduction, transportation and storage efficiencies while service enhancement comes from better delivery performance and fewer stock-outs for the retailer (Finch 2008: 393).

As stated earlier, logistics forms a vital part of supply-chain management. Logistics management coordinates and integrates all materials-based functions inherent in planning, forecasting, manufacturing or servicing and processing a product and distribution in order to fulfil the aims, goals and benefits of businesses. Usually the aim is to enable the business to keep ahead of the market changes where quality, price, response-time and service are crucial factors (Quayle & Jones 1999: 87). The goal is to link the market place and its distribution channels to the procurement and manufacturing operations in such a way that competitive advantage can be achieved and maintained. The benefit accrued should result in cost reduction, sales generation, improved service levels and increased productivity.

Citing the 2004 Council of Supply Chain Management Professionals, Rushton, Croucher & Baker (2006:11) indicate that the cost of logistics, as a percentage of gross domestic product for some selected countries is significant. For example the United States of America is 12 percent, United Kingdom 12 percent, Japan 13 percent, Germany 14 percent while the highest in the list is Mexico at 16 percent. This is an indication of the significant role played by logistics in the national economy of nations.

The logistics costs as a percentage of sales turnover vary from industry to industry. In a benchmark survey conducted in the United Kingdom by Dialog Consultants Limited, it was established that, generally speaking, the fast moving goods companies have lesser logistics costs when compared to heavy industries. For instance, the report indicates total logistics costs for soft drinks was 5,68 percent, spirits 8,1 percent, gas supply 11,98 percent, while cement is as high as 46,0 percent (Rushton *et al*. 2006:12). The coal mining industry could be compared to the cement industry as far as logistics and supply-chain management is concerned.

It is not uncommon for supply chains to experience bottlenecks, which are also referred to as constraints. The sources and causes of these bottlenecks vary according to industry and from time to time. To illustrate, the supply-chain system of the coal-mining industry in some countries, for example Taiwan, appears to be quite complex since the bulk of coal required by their power-generating company comes from a multiple of sources from all over the world. Their bottlenecks include coal allocation, fleet deployment and uncertainty of shipping operations (Tzeng, Hwang & Ting 1995:24-46).

In order to understand the constraints experienced in the supply-chain system it may be instructive to consider the theory of constraints (TOC). The theory is based on the recognition that in all organisations nearly all products and services are created through a series of linked processes. The linked process is the supply chain. Each process step has a specific capacity to produce output or to take in input and in every case, there is at least one process step that limits throughput for the entire chain. This process step is the ‘constraint’ (Bozarth & Handfield 2006:221).

Waller (2003:677) defines constraint as anything that limits an organisation, operation or a system from maximising its output or meeting its stated goals or objectives. There are physical constraints such as insufficient plant capacity, labour, capital, raw material and land. There are also non-physical constraints such as poorly motivated employees, workers’ absenteeism, lack of training, poor operating procedures, lack of flexibility on part of the union and bad scheduling. Such constraints or bottlenecks occur when there are materials or units accumulating upstream because the next operation has insufficient capacity to accept the load (Waller 2003:677).

A constraint is a linking factor that must be taken into consideration before a strategic option is considered. Before an organisation undertakes the risk-benefit analysis of a strategic option, possible constraints need to be taken into account (Anklesaria 2008: 139-140). The constraints along the supply chain can have the effect of increasing inventory and associated costs, slowing down the flow of goods to the consumer and reducing quality (Finch 2008: 619). A system constraint acts like the weakest link in a chain. Efforts to improve such a link will increase the strength of the chain. Once it is strengthened to the point that it is no longer be the weakest link and further improvement to it will do no good. In that case, a new weakest link needs to be identified (Finch 2008: 662) The movement of goods along the supply chain can be compared to the water flow through a pipe that has different diameters at various intervals. In such a situation, constraints are realised at the narrowest sections of the pipe where the water flow is limited. Increasing capacity at any other process step will not increase throughput for the entire process chain. Although improvement of capacity at the constraint point will improve throughput, the constraint itself will move to another point along the supply chain (Bozarth & Handfield 2006: 221). Managing constraints along the supply chain can directly contribute to the improvement of throughput, which will result in increased productivity. According to Simatupang, Wright & Sridharan (2004: 61) there are two ways in which a constraint-based approach can help managers improve the supply chain- Firstly it provides a reliable global performance measure which would help the supply-chain members to measure the progress for accomplishing the total revenues of the supply chain and secondly, it focuses on improvement efforts which would have a dramatic impact on the supply-chain performance.

According to Davis, Aquilano and Chase (2003:493) optimised production technology (OPT) is a production-planning and control method that attempts to optimise scheduling by maximising the utilisation of the bottlenecks in the process. Other models like the network optimisation model (NOM) are used to assess risks and rewards under a wide range of likely future operating environments. It provides a means of describing and measuring performance of all key operating characteristics within a supply chain. Such characteristics include material sourcing, facility infrastructure, processing, flows throughout the chain, cost, capacities and other internal and external factors (Gattorna 2003:90).

Constraints management is a framework for measuring the constraints of a system in a way that maximises the system’s capacity. The fact that it manages the most important part of the system, the part that determines its output, means that constraint management is actually a way of focusing on the most critical aspect of the system (Finch 2008: 660).

Furthermore, ERP is critical for the success of any supplychain system. An ERP is a system for managing organisational resources which includes people, resources and technology (Handfield & Nichols 2002:94). Once a seamless supply-chain system has been established, it is equally important to build strong organisational relationships within and between the supply-chain member organisations.

Organisational relationships are developed through better understanding of each other's processes and delivery performance in order to establish better ways to serve their customers. To ensure a solid working relationship, communication links with customers and suppliers must be established, maintained and used regularly. The parties involved must clearly establish objectives, expectations and potential sources of conflict in order to facilitate communication and joint problem-solving. Such communication enhances trust between buyers and suppliers leading to operational improvements and optimisation (Handfield & Nichols 2002:16).

Fauconnier and Kersten (1982:6) observe that coal mining is a complex undertaking requiring ingenuity in planning and execution at all levels, from mining operations to management and marketing. The execution of a successful supply-chain system is driven by strategic integration and information technology systems, business processes and cost-effectiveness throughout the value chain (Handfield & Nichols 2002:87). In pursuance of this study, critical elements that drive supply-chain systems and constraints as well as perceived remedies will be explored within the coal-mining industry in South Africa.

The mining and consumption of coal has serious environmental consequences leading to land degradation, water and air pollution (Cassedy & Grossman 2000). For example, the burning of coal increases the greenhouse gases in the atmosphere. The greenhouse phenomenon is created by the energy from the sun warming the earth's surface and the atmosphere creating a natural greenhouse effect (Kralgic 1992:25). Kralgic further categorises greenhouse gases as water vapour, carbon dioxide, methane, nitrous oxide and ozone.

1.2 THE SCOPE OF STUDY

In an effort to explore the coal supply-chain constraints in the South African coal mining industry this study has featured the leading mining companies nationally and looked at the energy contribution to sustainable development, coal mining impacts on the environment, legislation, and regulations governing the industry. The participants were selected from the five leading coal mining groups of companies in the country and institutions involved in the coal industry. These groups of companies produce over 80 percent of South African coal and four of them participated in the study: Anglo Coal, BHP Billiton, Xstrata, and Sasol. The participating institutions included the Chamber of Mines, Richards Bay Coal Terminal (RBCT), ESKOM (power utility), TRANSNET (rail transport logistics), Department of Environmental Affairs and Tourism (DEAT) and National Energy Regulator of South Africa (NERSA).

1.3 PROBLEM STATEMENT

Since the last quarter of 2007 South Africa has continued to experience electricity supply problems from the electricity supply company ESKOM. The whole country was adversely affected by power outages and the mining sector still operates 10 percent below capacity in an effort to try and conserve energy for the benefit of the country. Through NERSA, the government initiated an investigation into the entire electricity crisis. NERSA found that the problem was mainly due to the poor coal planning and procurement by ESKOM, which led to coal stockpile levels running low at the power plants (NERSA 2008a: 38-39).

As mentioned earlier, most of South Africa’s coal-mining industries are concentrated in the inland Mpumalanga coal fields where most of the coal-fired power plants are also located. In most coal-fired power plants, coal is received via conveyor belts, as ESKOM planned to build them over the coalfields with a tied coal mine for the ease of supply. The South coal-fired power plants run with long-term coal supply contract with the respective mines next to them. However, coal produced for export is transported by rail for a distance of approximately 650 kilometers to the Richards Bay Coal Terminal (RBCT) along the Eastern coast of Kwa-Zulu Natal. Handling capacity at RBCT has been a major constraint for export (DME 2009: 47).

The coal mining industry faces a huge environmental challenge as a result of coal-mining processes and coal combustion at power stations for generation of electricity. The mining process causes soil, water and air pollution, destruction of plants and land degradation among others, while coal use emits carbon dioxide and other greenhouse gases into the atmosphere during combustion at the power stations. Carbon emission is blamed for some significant percentage of pollutants which cause climate change.

1.4 OBJECTIVES OF THE STUDY

1.4.1 Primary Objective

The primary objective of this study was to determine the supply-chain constraints faced by the South African coal-mining industry with a view to developing a model that would minimise such constraints.

1.4.2 Theoretical Objectives

In order to achieve the primary objectives of the study, the following theoretical objectives were set:

- to review the literature on supply-chain management and how it relates to the coal-mining industry;
- to review, critically, the coal mining industry and its landscape. This will also include the historical development and the future outlook of the industry;
- to conduct an extensive study on the theory of constraints and how it relates to the coal-mining industry in South Africa;

- to explore and establish the impact of the industry on the environment.

1.4.3 Empirical Objectives

In order to establish the primary objective of the study, the following empirical objectives were set:

- to explore the supply chains of the coal mining industry;
- to determine the supply-chain constraints or bottlenecks experienced by the coal mines;
- to determine the environmental issues germane to the industry;
- to develop a model that would minimise the supply-chain constraints in the coal-mining industry.

1.5 RESEARCH QUESTION/S

The research question needed to address the primary objectives of this study in order to identify the supply-chain constraints in the South African coal mining supply chain and identify a model that would minimise such constraints.

How can the supply-chain constraints in the South African coal mining industry be identified and controlled in order to increase throughput and profitability?

1.6 RESEARCH METHODOLOGY

The research type used in this study fell within the qualitative research paradigm. The research design and strategy used were explained. Detailed coverage of the literature review, research paradigm, sampling techniques and selection of population and sample are provided. The methods of data collection, data recording, data transcription, data analysis (content analysis), evaluation, interpretation and conclusion are stated.

The validity and reliability (measure of trustworthiness) in the form of credibility, dependability and triangulation are stated. The process of theory building and ethical considerations for the study are also included.

1.6.1 Literature Review

The literature reviewed in this study included text books, journals, newspaper articles, selected items from the internet, companies' annual reports, and the government legislation and regulation publications. The literature reviewed provided a theoretical framework for the study through referencing other researchers' studies and experience in similar or related fields.

1.6.2 Empirical study

A qualitative research paradigm was used in this study. Willis (2007:8) defines a paradigm as a comprehensive belief system, a world view or framework which guides research and practice in the field. According to Merriam (2002:13), qualitative research is the method of enquiry that seeks to understand the phenomena within the context of the participants' perspectives and experiences.

1.6.2.1 Selection of participants

Non-probability sampling and more specifically purposive sampling was used in this study. The purposive judgment sampling is based on the researcher's knowledge of the research area and the important opinion-makers within the research area (Neuman 1997:205). Only experts in the coal industry, coal supply chain participated in the interviews. The chief executives of the organisations involved were approached and some of them offered to participate in the research while others chose to nominate participants who are professionals in the supply-chain field. The participants in the study were drawn from the selected organisations/institutions as follows: Anglo Coal (1), BHP Billiton (1), Xstrata (1) and Sasol (3); Chamber of Mines (1); Richards Bay Coal Terminal (RBCT) (1); ESKOM (2); TRANSNET (1); Department of Environmental Affairs and Tourism (DEAT) (1).

To compile the samples for this study, people in senior management in the above-mentioned organisations/institutions were contacted and some of them agreed to participate in the interview while others nominated experts in the coal supply-chain field. Some of the organisations, for example ESKOM provided two participants (an expert in coal and an expert in coal logistics). SASOL provided three participants (an expert in domestic coal-supply chains, in export and environmental issues and a third in safety issues).

1.6.2.2 Method of Data Collection

The primary sources of data in this study were collected from experts in coal supply-chain management. Other data were collected from documents collected from some of the participants, companies' annual reports, journals, books and from the internet. Hence, a qualitative research design is the most appropriate for this study.

The interviews were scheduled to last between 30-50 minutes, but some lasted much longer. There were no problems experienced during the interviews since all the respondents had received the questions to prepare in advance. The questions were unstructured (open-ended) in order to extract in-depth understanding of the coal-mining industry.

Unstructured interviews enabled the researcher to 'follow up particular interesting avenues that emerged from the interview and the participants are able to give a fuller picture' (Greef 2005: 296). Although the questions were open-ended, they were also focused so that the researcher could elicit pertinent information from the respondents.
In some instances, for example at ESKOM the researcher was invited to provide more details on the research project before an interview date was granted. The other organisations/institutions provided an interview date and a venue on acceptance of the request. It was not possible to meet the NERSA respondent who opted for interview via telephone.

Some of the participants provided the researcher with some documents to provide more detail on some of the answers from the research questions. The other method of data collection involved the use of companies' reports, sustainable reports and newsletters that provided more insights to the study. For example, the Department of Minerals Resources provided numerous publications on the mining industry while the Department of Environmental Affairs and Tourism provided Government Gazettes containing environmental legislation.

1.6.2.3 Data Analysis

Since the data collected were qualitative, content analysis was used. Content analysis is a detailed and systematic examination of the contents of a particular body of material for the purpose of identifying patterns, themes or biases. Content analysis is performed on some forms of human communication which include transcripts of conversations, newspapers, television clips, video recordings of human interactions and bulletin board entries (Leedy & Ormrod 2010:144).

According to Devlin (2006:198), content analysis involves the following steps:

- Read through all the written responses to the question in order to establish the views of the participants.
- Create a condensed list of the responses in order to establish themes and categories.
- Create a list of categories (no more than six or seven) that reflect the major topics which came up in interviews with the participants.
- Develop an operational definition of each category for other people to read and rate.
- Conduct an inter-rater reliability analysis on a sample of each category to determine inter-rater reliability.

The participants in this study were notified of the need for having the interviews recorded and agreed to the suggestion. An audio-digital data recorder was used to record all the interviews. The recorded interviews were then transcribed, categorised and synthesised for the final analysis. The emerging themes were coded and interpreted.

1.6.2.4 Reliability and Validity (Measures of trustworthiness)

Reliability in this study was ascertained through the triangulation method. Triangulation entails the use of different data collection methods within one study in order to ensure that the data is authentic (Saunders, Lewis & Thornhill 2003: 99). Triangulation is also a way of trying to enhance validity by looking at the issue from different angles for instance types of method or different analysis techniques. It can also be used to enhance richness of the data set (Lee & Lings 2008: 239). Multiple sources lead to a better understanding of the phenomena being studied (Willis 2007: 219).

In this study, triangulation was established by comparing the data collected from interviews with participants, field notes and those obtained from sources stated above.

A second way which was used to ensure the trustworthiness is member-checking. This was applied when the researcher interacted with the participants during the interview-planning stage and after interviews in order to gather any additional material from written feedback and compliments.

1.7 ETHICAL CONSIDERATIONS

Research as any other human activity can involve direct (or indirect) fraud, lies and wrong-doing. Misconduct in science has serious consequences. Therefore, normative guidelines and a code of ethics and rules are needed in order for academic institutions and organisations to monitor the integrity of science endeavours and to create ways to handle mistakes (Eriksson & Kovalainen 2008: 68).

The ethical issues for this study were contained in the research introduction letter that was sent to the participants on their acceptance to participate in the interview. The letter provided an undertaking of confidentiality between the interviewee and interviewer, anonymity and use of pseudonyms.

1.8 THE CONCEPTS DEFINED

The following are some of the commonly used terms in the coal-mining industry supply chain:

Coal

Coal is a combustible black or brownish-black sedimentary rock composed mainly of carbon and hydrocarbons and is a non-renewable energy source categorised as fossil fuel. Coal is a fossil fuel and a primary source of energy.

Coal reserves

Coal reserves are beds of coal still in the ground waiting to be mined. The world recoverable coal reserves are available in about 70 countries, but 13 of them including South Africa possess the bulk of it (Abbot, Apostolik, Goodman, Horstmann, Jenner, Jewell, Labhart, Maragos, May, Sunderman, Parke, Stein, Wengler & Went 2009: 55)

Coking coal

Coking coal is the coal used in the metallurgical industry to produce iron and steel. The product 'coke' is prepared from certain bituminous coals by process of carbonisation which involves heating coal at very high temperatures in the absence of air. After the loss of the volatile components of coal through heat, the residual material is coke, which is then used in the blast furnaces for the production of iron and steel (Crawford 1993:5).

The South African coal is less reactive, harder and contains lower sulphur content as compared to the coal from the Northern hemisphere. These are the bituminous or thermal coals and anthracite which are used as coking coal in the metallurgical plants (Lang 1995: 20).

Fossil fuel

Fossil fuel is defined as ‘conventional’ fuel comprising oil, gas and coal (Kruger 2006: 147). Coal constitutes the largest of the fossil fuels in the world (Crawford 1993:66).

Liquefaction

Liquefaction is the process of converting coal into liquid fuels. In South Africa, liquefaction is done by SASOL using a technology called Fischer-Tropsch (FT) to convert coal and natural gas into synthetic fuels and chemicals. The conversion of natural gas to liquid fuel is called GTL process (SASOL 2008: 68).

Renewable energy

Renewable energy is the alternative to the conventional energy that is derived from fossil fuels (oil natural gas and coal). Renewable energy includes hydro, solar, wind, biomass, ocean currents and geothermal forms of energy (Crawford 1993: 4).

Carbon credits

Governments and some international bodies like the World Bank issue emission permits to companies and institutions to emit a certain amount of pollutants into the atmosphere. These are called ‘emission allowances’ or ‘emission credits’ (carbon credits). The companies and institutions requiring to increase emissions may do so by buying carbon credits from those companies that emit less pollutants through a process called ‘emission trading’. This means that the buyer pays a charge for polluting and the seller is rewarded for reducing carbon emission to below the set limit or cap (Abbot *et al.,* 2009:86).

Supply-chain management (SCM)

Supply-chain management (SCM) evolved from the traditional focus of purchasing and logistics from the mid-1960’s to the 1990’s. The SCM is a source of competitive advantage with the potential for performance improvements in customer service, profit generation, asset utilisation and cost reductions (Kampstra, Ashayeri & Gattorna 2006: 312). The supply chain involves the upstream suppliers of raw materials to companies that manufacture products and supply-finished goods downstream through distribution centres to retailers that sell them to the end users/consumers (Barnes 2008: 211).

Pull versus push supply chain

When an order is initiated from the lowest end of the distribution chain by the retailer, it is a ‘pull’ system (Waller 1999: 505). When the order is initiated by the supplier at the end of the supply chain network, it is a ‘push’ system (Waller 1999: 507). A pull system enables the upstream to produce goods based on customer demand at the point of purchase. A push system produces goods based on sales forecast and then the goods are moved through the supply chain channel and stored as inventory awaiting orders from the customer (Evans & collier 2007: 370).

Theory of constraints (TOC)

The Theory of Constraints (TOC) philosophy was developed in 1990 by Goldratt (Goldratt 2001-2009:9). The TOC philosophy is based on the recognition that nearly all products and services are created through a series of linked processes (Bozarth & Handfield 2006:222).

Inbound logistics

Inbound logistics is involved in a generic role in purchasing and delivering goods from the suppliers for manufacturing purposes. The inbound logistics activities are aligned with the operations, marketing, sales and services (Porter 1985:39-40). In essence, inbound logistics is concerned with bringing raw materials from suppliers to the manufacturers and managing them until they are converted into finished goods (Van Weele 2003:10).

Outbound logistics

Outbound logistics is concerned with physical movement of finished goods from factory or manufacturing warehouses to the customers.

Third- party logistics (3PL)

The Third-Party logistics involves outsourcing logistics services from the third-party companies. The 3PL companies are specialists in logistics functions and they are preferred because they perform the function more efficiently and economically compared to some in-house performance (Stroh 2006:215). 3PL logistics provides other support services to manufacturing clients that include warehousing, order processing, data processing and shipping (Langford 2006:364).

Fourth-party logistics (4PL)

The Fourth-party logistics (4PL) are logistics consulting companies as well as logistics service providers. In their consulting roles they do 'SWOT' analysis (strength, weaknesses, opportunities and threat) for clients to establish reasons for logistics outsourcing services (Stroh 2006:216). The 4PL role enhances supply-chain collaboration by providing an 'optimisation tool' to coordinate the product flow through the supply-chain channel (Kampstra, Ashayeri & Gattorna 2006: 314).

1.9 THE ROLE PLAYERS IN THE SOUTH AFRICAN COAL-MINING INDUSTRY

The key role players in the South African coal-mining industry are: the mining companies, Department of Mineral Resources (DMR), Department of Environmental Affairs and Tourism (DEAT), National Energy Regulator (NERSA), ESKOM, TRANSNET, Anglo Coal, BHP Billiton, Exxaro, SASOL, Xstrata, Richards Bay Coal Terminal and the Chamber of Mines of South Africa.

ESKOM

ESKOM is a South African government-owned utility company which generates approximately 95 percent of electricity used in the country and approximately 45 percent of the electricity used in Africa. The utility company commenced operations in 1923 as the Electricity Supply Commission (ESCOM) and was later renamed ESKOM, producing electricity for the government departments, railways, harbours, mining companies and the local industries (Ashton 2010: 15). Today ESKOM produces electricity for all sectors in the country covering over 4 million customers (ESKOM 2009: iii). The core business of ESKOM is generation, transmission and distribution of electricity for all sectors in the country (ESKOM 2009: i).

TRANSNET

TRANSNET is a South African government-owned corporation responsible for major transport infrastructures which include railways, harbours and pipe lines. That makes it the leading logistics company in the country. The corporation operates through business units and the unit responsible for rail transport is Transnet Freight Rail (TFR). The export coal rail line runs from Witbank in Mpumalanga to Richards Bay Coal Terminal, on the eastern coast of Natal, hence, the importance of TFR to the coal mining industry.

SASOL

South African Synthetic Oils (SASOL) is a South African public company founded in 1950. The company converts coal and natural gas into liquid fuels and supplies a third of South Africa's liquid fuel requirements. SASOL is the country's single largest industrial investor contributing about 4.7 percent to the growth domestic product (GDP). It is also the largest chemical feedstock producer in the country (SASOL 2008: 69-70).

RICHARDS BAY COAL TERMINAL (RBCT)

Richards Bay Coal Terminal (RBCT) is the largest single coal export terminal in the world exporting more than 69mtpa (million tons per annum) of coal. The port commenced operations in 1976 with an annual export capacity of 12mtpa. The handling capacity had reached 76mtpa by 2009 and 91mtpa in 2010 (Chamber of Mines 2009: 29). The RBCT is owned by 11 coal mining companies with the leading coal mining houses as the main shareholders (DME 2009:3).

CHAMBER OF MINES OF SOUTH AFRICA

The Chamber of Mines of South Africa is about 120 years old, having been established in 1889. Its role is serving, promoting and protecting the interest of South African Mining industry. This role can also be stated as "protector of the mutual prosperity of the South African mining industry" (Chamber of Mines 2009:1).

The Chamber publishes a range of books, reports and newsletters, which contain information related to its lobbying and advocacy role. The publications are used to inform and interact with the Chamber's different audiences. It also liaises with the government and other coal producing countries in Africa on mining issues that are beneficial to the stakeholders (Chamber of Mines 2009: 7-9).

1.10 CHAPTER CLASSIFICATION

A summary of the contents of all the chapters in this study is provided as a navigation guide:

CHAPTER ONE: Introduction and background to the study.

This chapter discusses the framework, background and scope of the study. The problem statement and the primary objective for the study are stated. The theoretical and empirical objectives plus the research question are also addressed. Subsequently, the chapter classifications, common terminologies used in the coal-mining industry and a summary of the leading role players in the South African coal-mining industry are provided.

CHAPTER TWO: The **South African coal-mining industry.**

This chapter discusses the landscape of coal mining in South Africa. The history of coal and its characteristics are explored. . It also reflects on the history of coal mining and its development over time. The role played by the industry in providing feedstock for the generation of electricity for the South African economy is also discussed. In addition, the chapter examines the critical role played by coal in expediting the development of diamond, gold and other minerals that have continued to create massive wealth for the nation.

CHAPTER THREE: Coal mining and the environment.

This chapter discusses the environmental issues in the South African coal-mining industry and how it affects the coal supply chain. It comments on sustainable development, the Kyoto Protocol 1997, the Copenhagen Earth Summit 2009 and the King Report III. The chapter also investigates the environmental legislative environment and the impact of coal mining and coal use, carbon credits and clean coal technologies on future environmental conditions.

CHAPTER FOUR: Supply chain and logistics management.

The chapter provides an in-depth description and definition of supply-chain management and its role in the economy. The types of supply chains, the demand side and supply side of a supply chain, collaboration and use of technology to enhance information flow are also discussed. Logistics is described, defined and the critical role that it plays in the supply chain is articulated.

CHAPTER FIVE: Theory of Constraints (TOC).

This chapter discusses the theory of constraints: its' origin, meaning and effects on business. The cause of constraints or bottlenecks and management of the same are stated. The chapter also shows how managing constraints can improve throughput, productivity and profitability.

CHAPTER SIX: Research Methodology.

This chapter declares the research methodology used for this study. The research design and strategy used are explained. Detailed coverage of the literature review from the stated sources, research paradigm, sampling techniques, selection of population and sample are provided. The methods of data collection and data analysis are stated. The validity and reliability (measure of trustworthiness) in the form of credibility, dependability and triangulation are stated. The chapter also includes the process of theory building and ethical considerations for the study.

CHAPTER SEVEN: Data presentation and analysis.

This chapter looks, critically, at the transcribed research data in detail until saturation is realised. The themes emanating from the data are coded into main themes and sub-themes and classified for evaluation and interpretation in order to support the outcome of the study.

CHAPTER EIGHT: Conclusion and recommendations.

This chapter provides a summary of the entire study and makes recommendations based on the literature review, the primary data, as well as the secondary data gathered throughout the study. The chapter provides a reflection on the study and declares whether or not the objectives for the research have been achieved. The recommendations drawn from the study and the main objective of the study to develop the proposed model for the South African coal mining industry supply chain are presented.

CHAPTER 2
THE SOUTH AFRICAN COAL MINING INDUSTRY

2.1 INTRODUCTION

This chapter describes the landscape of the coal mining industry in South Africa and its socio-economic impact on the economy. An outlook on the global and South African coal industry is provided, highlighting the reserves, production, consumption and trade of coal. The chapter also provides detailed accounts of the leading coal mining companies, key role-players, a South African coal mining business model and the future of coal mining in South Africa.

2.2 COAL AND ITS PROPERTIES

Coal is a fossil fuel and a primary source of energy. Its formation in the Southern hemisphere was preceded by an ice age which captured its energy in prehistoric times approximately 300 million years ago. With the melting of ice, swamps formed in valleys allowing the establishment of thick vegetation, which had a short lifespan. After the death of that vegetation and accumulation over many years, undergoing a slow decaying process, peat was formed which eventually turned into coal seams from which coal is mined today (Anglo Coal 2007:47).

Coal is a combustible black or brownish-black sedimentary rock composed mainly of carbon and hydrocarbons and is a non-renewable energy source categorised as fossil fuel. Fossil fuel is defined as ‘the result of anaerobic decay of ecologically deposited vegetation that had to undergo metamorphosis due to pressure and temperature over time’ (Kruger 2006:43). Coal is regarded as a non-renewable energy source since it takes millions of years to create by natural means that is beyond human manipulation. The energy in coal comes from the energy stored from dead plants that have been lying at the bottom of swamps covered by layers of water and dirt for the past millions of years (Abbott *et al.,* 2009:35).

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).

The South African coal properties comprise: a moisture content (2 - 40 per cent), sulphur content (0.20 - 8 per cent) and ash content (5 - 40 per cent), calorific value – heat contents (CV), volatile matter (VM) fixed carbon (FC) and a grindability factor. These properties affect the value of coal as a fuel and cause environmental problems when coal is in use. After beneficiation, coal becomes relatively low in ash and sulphur contents and has high calorific value (World Bank 2007:282).

2.3 TYPES OF COAL

The World Bank (2007: 282) states that coal classification is based on the content of volatiles and varies between countries. There are six types of coal, but typically only five types are commonly used. The one type known as 'peat' is the precursor of coal and it is used in industries in a few countries for example England, Ireland and Finland. The Global Association of Risk Professionals (Abbott *et al.,* 2009: 53) categorises coal as follows: lignite, sub-bituminous coal, bituminous coal, anthracite and graphite.

<u>Lignite:</u> Also referred to as "brown coal", is the lowest rank of coal. It is considered to be relatively young as compared to the other types. It contains 25 to 35 percent carbon and is mainly used in power plants to generate electricity.

Sub-bituminous coal: Also known as "dull black coal" or "soft coal", sub-bituminous coal has higher heating values than lignite. It contains 35 to 45 percent carbon and it is also mainly used as fodder at power plants for the generation of electricity.

Bituminous coal**:** Also known as "black or dark brown coal", bituminous coal contains 45 to 86 percent carbon and is used in the power utilities for the generation of electricity and in metallurgy industry as coke for the production of iron and steel. Most coking coal is bituminous.

Anthracite: Also referred to as "hard coal", anthracite is the highest ranked coal and it is hard, glossy and black. It contains 86 to 97 percent carbon and is primarily used for residential and commercial space heating.

Graphite**:** Is in the same category as anthracite and it is mainly used in pencil making and as a lubricant when powdered.

The World Bank (2007:282) further classifies the five types of coal above as hard and brown coal.

Hard coal**:** Comprises coking coal (used to produce steel), bituminous and anthracite coals (used for fuel and power generation).

Brown coal: Sub-bituminous and lignite coals (used mostly as on-site fuel).

The following section discusses the historical and modern uses of coal.

2.3.1 The ancient use of coal

As a primary source of energy coal has undergone a transformation in the manner in which it has been used over time. The earliest use of coal was for heating and cooking, then as fuel for running the steam engine during the industrial revolution. Coal usage dates back some 120 000 years to the Stone Age and over 10 000 years ago in Germany and China respectively. In Britain the first coal usage is estimated to be between 2000-3 000 years BC (Chadwick 1994:150).

The earliest coal deposits in South Africa were formed in the Karoo sediments which extended to Wankie in Zimbabwe and Maamba in Zambia. The early African civilisation called coal "the black stone that burns" and used it to make fire for cooking, heating and smelting metallic ores (Lang 1995: 26-28).

2.3.2 Modern use of coal

Some of the modern uses of coal include its use as fuel, making coke, gasification, and liquefaction among others.

Coal as fuel

Coal is mainly used as solid fuel to produce electricity and heat through combustion. Approximately 39 per cent of the world's electricity production uses coal as fuel (Chamber of mines 2009: 25). SASOL operations include the conversion of coal into liquid fuels and gas into liquid fuels using Fischer-Tropsch synthesis. The company provides the country with a third of its liquid fuel requirements (SASOL 2008: 83).

Making coke

Coke is a solid carbonaceous residue delivered from low-ash, low-sulphur bituminous coal from which volatile constituents are driven off by baking in an oven without oxygen at high temperatures of about 1000 degrees Celsius in order that the fixed carbon and residues are fused together. The product 'coke' is then used as fuel and as a reducing agent in metallic smelters in a blast furnace. Coke from coal is a greyish substance that includes tar, ammonia, high oils and 'coal gas'. Carbonisation is also used in the manufacture of organic chemicals from coal (Crawford 1993: 5).

Gasification

Coal gasification is a process in which coal is broken down into smaller molecules by subjecting it to high temperatures and pressure using a calculated amount of oxygen and water/steam leading to the production of syngas (a mixture of carbon monoxide and hydrogen) (SASOL 2008:50). Gasification can also be described as the process in which pure gas is yielded by burning dry ash-free-coal using oxygen and steam. Pure gas is utilised for power generation, heating and other industrial applications (Coetzer & Kruger 2004:90). The new clean coal technologies use gasification in integrated gasification combined cycle (IGCC) power plants to generate electricity (Lennon 1997: 45-46).

Roods (2009:7-8) describes underground coal gasification (UCG) as a method of converting coal deep underground into a combustible gas which can be used for industrial heating, power generation or for the manufacture of hydrogen, synthetic industrial gas or other chemicals. The gas can be processed to remove carbon dioxide before it is passed to the end users, thereby providing a source of clean energy with a minimum of greenhouse gas emissions. The process of gasifying coal underground and bringing energy to the surface for subsequent use has become an attractive technology as clean energy sources are sought in the world (SASOL 2004:15).

The process of UCG involves drilling two boreholes from the surface, one to supply oxygen and water/steam and the other one to bring the product gas to the surface. After coal is ignited underground, oxygen and water/steam are pumped into the injection well to create a controllable burn. This process was started in the former Soviet Union in 1930's and trials have been conducted in Australia, China and South Africa by SASOL (ARGO Energy 2010:1). According to Roods (2009:7-8) the benefits from UCG include:

- The mining of coal that has been difficult to mine (UCG has 95 percent efficiency in coal extraction compared to conventional method of about 37 percent);
- it is commercially competitive in energy supply;

- there is no waste product that messes up the environment (decrease in environmental degradation footprint);
- there are numerous uses of gas (electricity generation, fuel gas production, industrial heating, raw gas and others); and
- there is increased efficiency in coal use.

Liquefaction

Coal can be converted into liquid fuels such as gasoline or diesel by several different processes. SASOL is a world leader in the conversion of coal into liquid fuels using the Fischer-Tropsch synthesis, a process originally used in Germany during the Second World War. The process involves gasifying coal into syngas (a balanced mixture of carbon monoxide and hydrogen) while the syngas is condensed using Fischer-Tropsch catalysts to make light hydrocarbons which are further processed into gasoline via Mobil M-gas process (Dry 2010:1). The coal liquid-fuel production methods release more carbon dioxide in the conversion process than in the normal gasoline processing from the refineries. Syngas is also converted into methanol which is used as a fuel, fuel additive or it is further processed into gasoline (SASOL 2008:20-21).

Auto manufacturers are trying Fischer-Tropsch liquid as a viable alternative fuel in diesel engines. This offers important benefits compared to diesel, reducing nitrogen oxide, carbon monoxide and particulate matter (California Energy Commission 2010:2).

2.4 WORLD RECOVERABLE COAL RESERVES, PRODUCTION, CONSUMPTION AND TRADE

Coal is an important energy source contributing approximately 39 percent of the total world energy consumption. The bulk of the global coal reserves and production are in 13 countries, which includes South Africa. Most coal is consumed in the countries where it is produced leaving only approximately 16 percent of the global production for trading (DMR 2009:44).

2.4.1 World recoverable coal reserves

Coal is mined in over 100 countries in the world. According to DMR (2009:44), the global recoverable reserves of coal amount to approximately 411 321 million tons (Mt). The top six nations which possess the most coal reserves are led by the United States with reserves of 108 950 Mt followed by China 62 200 Mt, India 54 000, Russia 49 088 Mt, Australia 36 800 Mt and South Africa 30 408 Mt. Lok (2009:22) estimates that at the current rate of consumption the world coal reserves could only last another 150 years.

Citing the World Energy Council, the Chamber of Mines (2009:25) reports that the world's total anthracite, bituminous, sub-bituminous and lignite coal proven reserves have fallen from 847.5 billion tons in 2007 to 826 billion tons in 2009. The following table shows the world recoverable coal reserves, production and exports in the various countries.

Table 2-1 World Recoverable Coal Reserves, Production and Export, 2008

	RESERVES			PRODUCTION			EXPORTS		
COUNTRY	**Mt**	**%**	**Rank**	**Mt**	**%**	**Rank**	**Mt**	**%**	**Rank**
Australia	36800	8.9	5	397.8	5.9	4	252.2	26.6	2
Canada	3471	0.8	11	68.1	1.0	11	33	3.5	7
China	62200	15.1	2	2761.4	40.6	1	47.3	5.0	6
Colombia	6436	1.6	9	78.6	1.2	10	74.0	7.8	4
India	54000	13.1	3	521.7	7.7	3	1.4	0.1	11
Indonesia	1721	0.4	12	284.2	4.2	6	214.4	22.6	1
Kazakhstan	28170	6.8	7	108.7	1.6	9	27.2	2.9	8
Other	8716	2.1		719.2	10.6		52.9	5.6	
Poland	6012	1.5	10	143.9	2.1	8	7.8	0.8	9
Russia	49088	11.9	4	326.1	4.8	5	101.7	10.7	3
South Africa	30408	7.4	6	252.2	3.7	7	57.9	6.1	5
Ukraine	15351	3.7	8	59.6	0.9	12	4.32	0.5	10
USA	108950	26.5	1	1 075	15.8	2	74.0	7.8	4
TOTAL	**411321**	**100**		**6796.7**	**100.0**		**948.0**	**100**	

Source: Department of Mineral Resources (DMR 2009: 4)

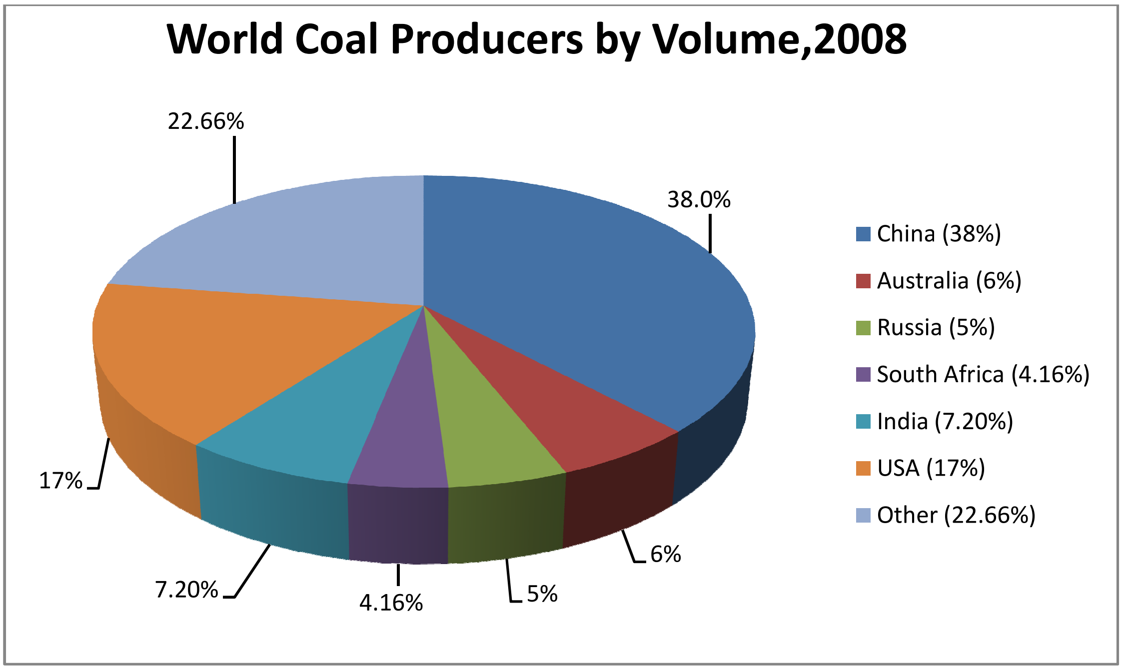
The table 2-1 above shows the total world coal reserves of 411 321 million tons (Mt), with the United States leading with 108 950 million tons representing 26.5 percent of the total world reserves. The other producers are ranked according to their reserves.

In 2008 China was the leading world coal producer, producing 40.6 percent of the total world production. Australia was the world leading exporter with exports of 252.2Mtpa of coal while South Africa was the sixth largest world producer and fifth largest exporter, exporting 57.9 million tons in the same year. The South African coal reserves were 30 408 million tons in 2008.

2.4.2 World coal production

Graph 2-1 shows the six leading coal producers in the world in 2008.

Graph 2-1 Six Top World Coal Producers, 2008



Source: (DMR 2009: 44)

Graph 2-1 shows the world's leading producers of coal by volume in 2008. The leading producer was China (38 percent) followed by United States (17 percent). In the other leading positions were third India (7.20 percent), fourth Australia (6 percent), fifth was Russia (5 percent) and in the sixth position was South Africa. The other coal producers produced 22.66 percent (DMR 2009: 44). In 2007 the ranking order of coal production was same as in 2008 (DME 2008: 42).

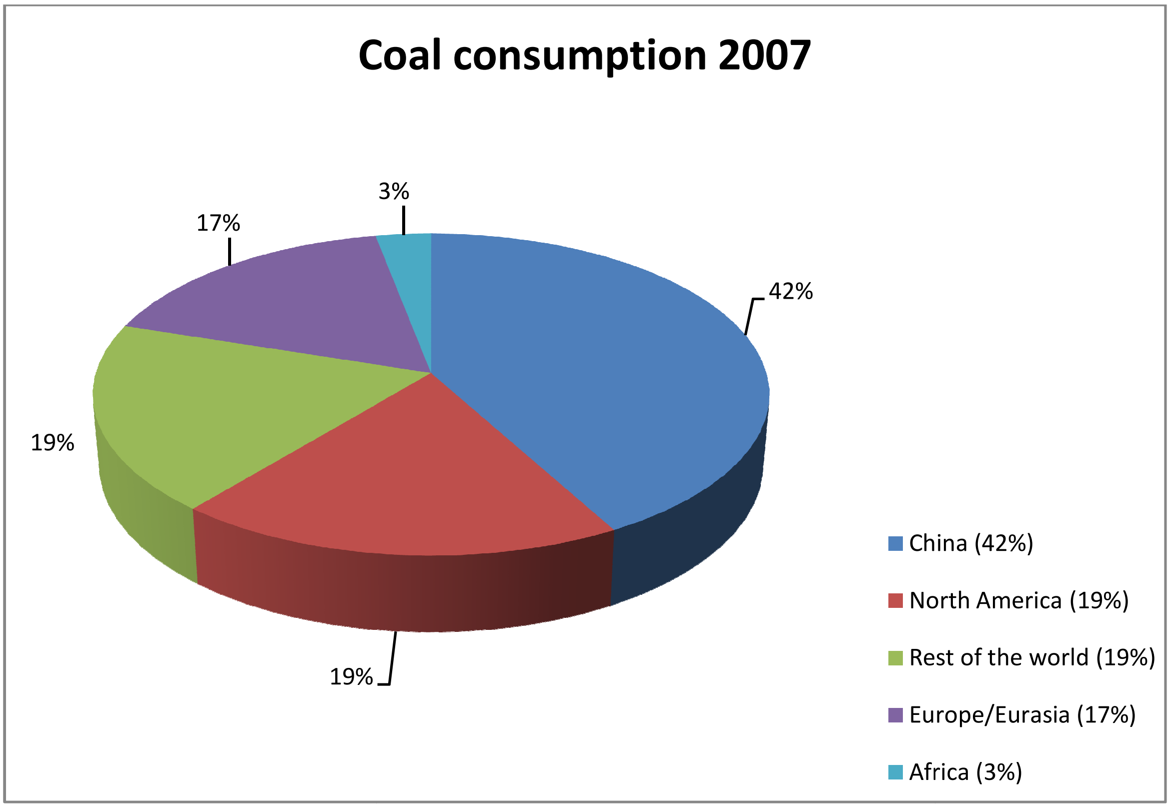
The global coal production grew by 6.2 percent from 6 397 Mt in 2007 to 6 797 in 2008 driven mainly by hard coal production. Hard coal comprises coking coal used in smelters to produce steel and also the bituminous and anthracite coal used for fuel and electricity generation. The leading producer is China accounting for 40.6 percent followed by the United States 15.8 percent, India 7.7 percent, and Australia 4.8 percent. South Africa is ranked number 7 for producing 252.2 Mt amounting to 3.7 percent of the total global production as indicated in the above table (DMR 2009:44).

In 2005, Russia had 220 coal mining companies comprising 96 deep mines and 124 open cast mines. Kuznestsc is the leading coal producing area accounting for about 55 percent of Russia's total output. However, growth in this region is limited by an internal transport system and lack of suitable port infrastructure. The transportation of Russia's export coal to the ports contributes over 30 percent of the export price (Flook & Leeming 2006:2) The world coal production in 2007 reflected an increase of 38 percent of coal production in the last 20 years. The production increase was due to faster economic growth in Asia that triggered increased demand for energy (Abbott *et al.,* 2009:54).

2.4.3 World coal consumption

The following graph 2-2 shows the global coal consumption in 2007 with China as the leading consumer (42 percent), North America second (19 percent), Europe and some Asian countries (17 percent), Africa (mainly South Africa 3 percent) and the rest of the world (19 percent).

Graph 2-2 World Coal Consumption, 2007



Source: Inside Mining, 2008: 22

The world population is estimated to grow by 25 percent in the next 25 years, thus a considerable increase in energy demand can be anticipated. Lok (2009:22) concurs with the research concluded by the American company Peabody (the world's largest coal mining company) that, in order to meet the global energy demand, investment is needed in other energy sources such as nuclear and renewable sources.

The world coal consumption increased in 2008 by 6.8 percent from 6 479 Mt to 6 948 Mt. This was higher than the average growth for the past six years which was 6.3 percent. All the coal categories rose considerably. China was the leading consumer with a growth of 13.1 percent. Consumption also rose in Russia (19.4 %), Indonesia (10.9%) and India (10.1%). However, consumption declined in South Africa by 4 percent (DMR 2009: 44).

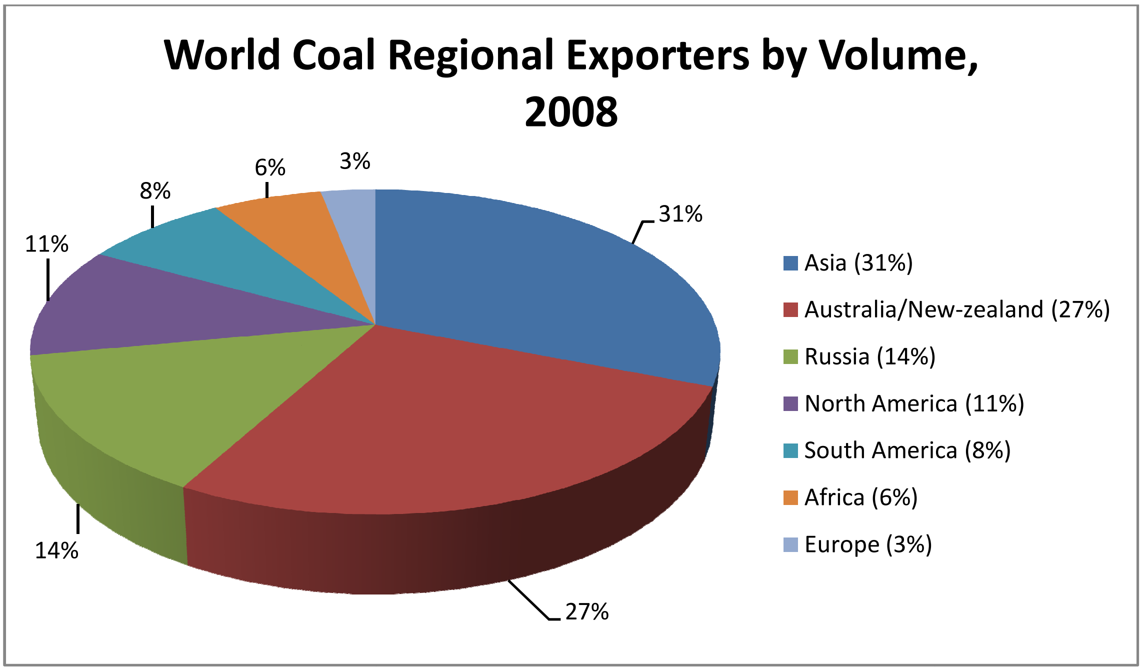
The two graphs above provide the proof that the world's coal is mainly consumed in the countries where it is produced. Out of the total global coal production, only approximately 16 percent is traded (exported) by a few countries, which include Australia, South Africa, U.S., China, Russia, Indonesia, Colombia and Venezuela. Chadwick (1994:154) believes that although coal could lose its share of the energy market gradually, overall demand will grow slightly, even with the extra costs of the environmental compliance. Coal presently fuels about 39 percent of the world's electricity and about 56 percent of the global consumption is in Asia (GARP 2009:56-57).

It is estimated that about two-thirds of global coal is used for power generation and most of the other one-third is used to make steel and cement. , Smuts (2008:33-37) believes that in the next 20 years, over 70 percent of the coal demand will come from China and India. In 2008 coal accounted for approximately 39 percent of the world's electricity generation. Demand for thermal coal is driven by demand for electricity and is also affected by availability and price of competing fuels such as oil and gas as well as nuclear power. Driven by varying degrees of deregulation in electricity markets, customers now focus more on spot pricing, deviating from the usual traditional long-term buying contacts (Anglo Coal 2008:49).

2.4.4 World coal trade

Graph 2-3 shows the world's coal exporters by region in 2008.

Graph 2-3 World Coal Exporters by Region, 2008



Source: DMR, 2009:45

The regions starting with the leading exporters are shown as Asia 31 percent, Australia 27 percent, Russia 14 percent, North America 11 percent, South America 8 percent, Africa 6 percent and Europe 3 percent.

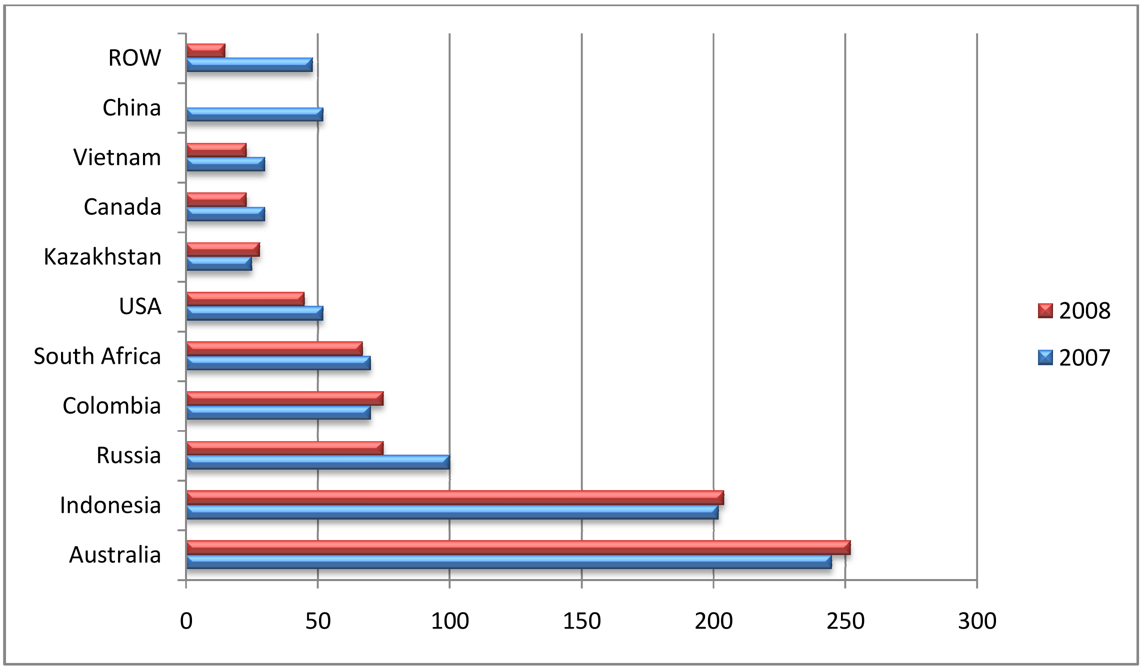
Presently, the international trade in coal is dominated by coal demand in Europe and Asia. These are the regions with rapid economic development and Europe, in particular, requires coal with less sulphur content which can only be imported. The South African coal has lower sulphur content and it meets that specification. Watch (2009:1) states that coal with very low sulphur content of 0.2 percent is in big demand for power generation as it meets the mandated sulphur dioxide emission in most European countries. In Britain, for example, power plants are mandated to use coal with a sulphur content of 0.18 percent. Coal in Asia is basically imported to meet the rapid economic development that has taken place in the last generation or so. Besides, most of the fast-growing Asian economies like Japan and India have limited coal reserves. Only China has abundant coal reserves, however, its consumption level is equally high to have extra for export. In 2002 only 16 per cent of coal produced was traded comprising

622.9 Mt of which 65.3 percent was in the Pacific trade and 34.7 percent was in the Atlantic trade segment. The Pacific segment covers the Asian and Pacific countries and it is controlled from Australia. The Atlantic segment covers the European countries and it is directed from Rotterdam, Netherlands and Richards Bay (Ekawan & Duchene 2006: 1487)

Citing the IEA report, the global hard coal seaborne traded marker shrunk by 13.5 percent to 793 million tons in 2008 versus 917 million tons recorded in 2007. One of the key reasons for reduction in the global coal trade was withdrawal of China from the export market. In 2007, China exported 54 million tons of hard coal and that export fell to zero in 2008 due to domestic coal demand (Chamber of Mines 2009: 25).

Graph 2-4 shows the world hard coal exporters in 2007 and 2008.

Graph 2-4 World Hard Coal Exports, 2007 and 2008



Source: Chamber of Mines 2009: 28

The graph illustrates the world hard coal exports by nations in 2007 and 2008. Hard coal denotes the categories of coal that include bituminous and sub-bituminous coals and anthracite. Bituminous and sub-bituminous coals are mainly used for power generation and anthracite is used as coking coal in the metallurgy industry. These three coal categories are usually the export type. The leading exporter in 2007 and 2008 was Australia exporting about 245 Mt in 2007 and 252.2 Mt in 2008. A remarkable indication in the graph is that China, as pointed out earlier, did not export any coal in 2008 because of increased domestic demand (Chamber of Mines 2009: 28).

2.5 SOUTH AFRICAN COAL RESERVES, PRODUCTION, CONSUMPTION AND TRADE

Coal mining is a mature industry in South Africa which started approximately 125 years ago (Malinkewitz 2008:1)**.** The industry has been instrumental in the development of a number of industries which either supply the mining sector or use its products. The most remarkable fact is that ESKOM uses most of the coal mined in South Africa to generate about 88 percent of the electricity generated in the country. The industry also provides coal used in the metallurgical industry (coking coal) used in the production of iron and steel and in the production of liquid fuels (Coal-To-Liquid) CTL. It is also used in industries and homes for space heating and as a trading commodity by merchants (Chamber of Mines 2009:19).

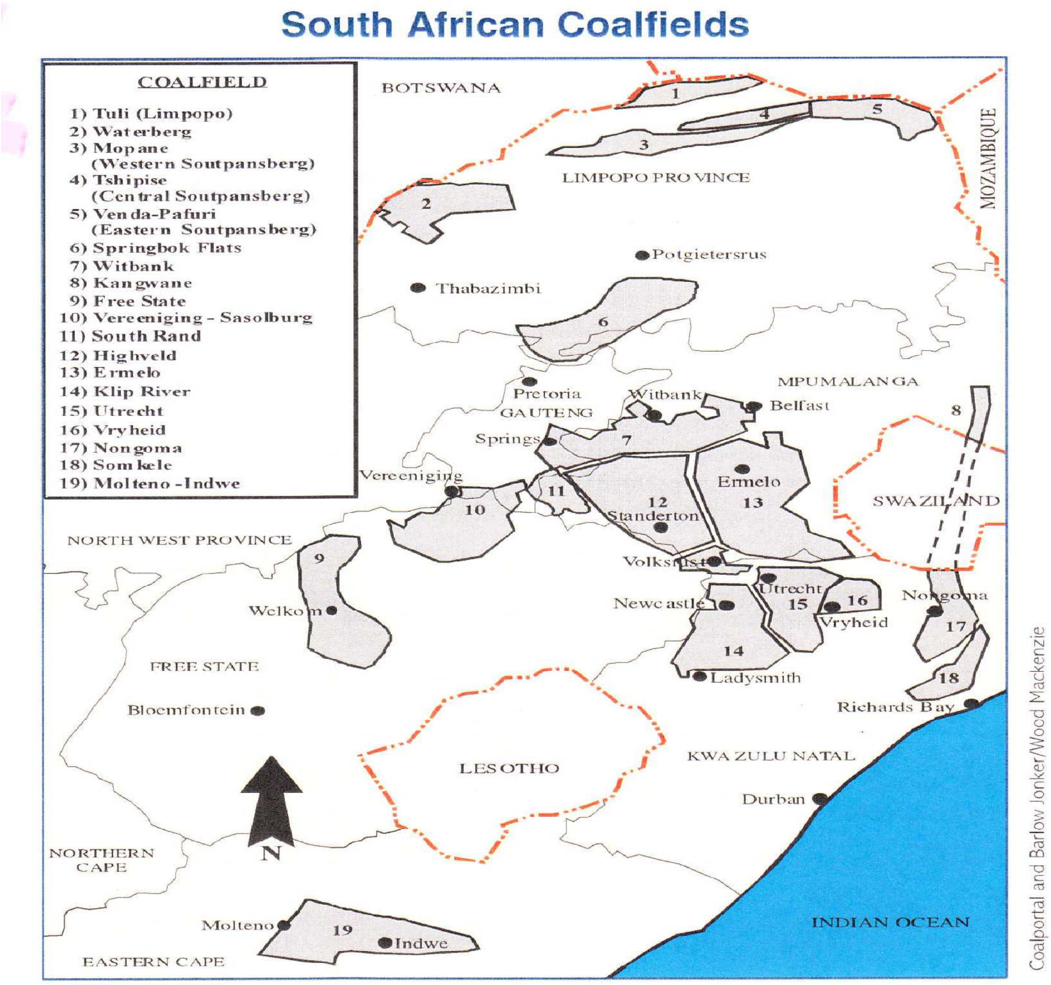
2.5.1 South African coal reserves

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 and Kwa-Zulu Natal 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. The area 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).

The following map shows the distribution of the South African coalfields.

Map 2-1: South African Coalfields, 2008



Source: Prevost 2008:6

Map 2-1 shows that most of the South African coal reserves are concentrated in the areas of Witbank, Ermelo, Highveld in Mpumalanga, and Waterberg in Limpopo.

There were 73 collieries in South Africa in 2007. A number 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 mining companies called junior miners and that includes the Black Economic Empowerment mining companies. The national distribution of the collieries are: Free State (2); Gauteng (1); Kwazulu-Natal (7), Limpopo (2) and Mpumalanga (61). The five leading mining companies involved in the exploitation of coal from these coalfields are Anglo Coal, BHP Billiton, Exxaro, Xstrata and Sasol (DME 2007:44).

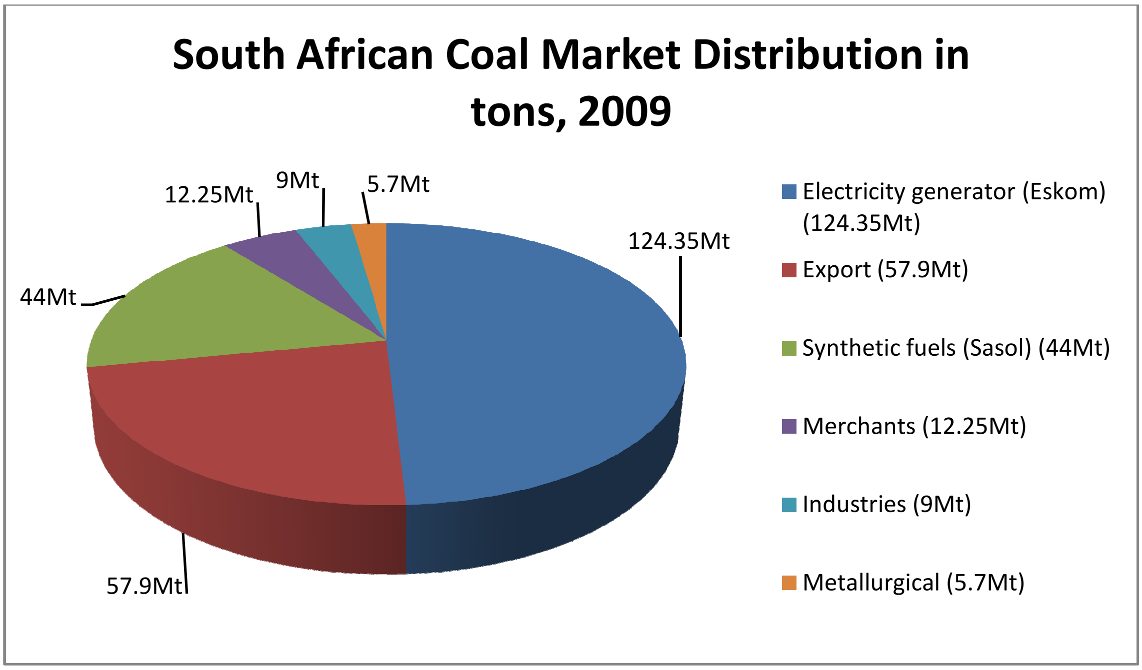
2.5.2 South African coal production

South African coal production has stagnated since 2004 while consumption by ESKOM has risen to meet power demand. The scenario puts ESKOM in competition with the other domestic consumers, resulting in price hikes and this has forced ESKOM to use washed discarded coal from the big coal exporters in order to meet their requirements. The demand will continue to outstrip supply for some time until new coal mines come on stream (Smuts 2008:36).

Over 80 percent of saleable coal production in South Africa is supplied by mines controlled by the largest five mining groups: Anglo Coal, BHP Billiton, Exxaro, SASOL and Xstrata. The rest is produced by the smaller mines (junior miners) with Black Economic Empowerment (BEE) partners. About 75 percent of coal mined in South Africa is used locally, mainly for electricity generation (ESKOM power plants) and for liquid fuels (SASOL) (ESKOM, PED 2008:1). In 2008, the South African coal market was estimated to be 252.2 Million tons (Mt) comprising 194.3 Mt for the domestic market and 57.9 Mt for export. Based on these numbers (DMR 2009: 48) the coal produced distribution ratios are as follows: power generation - ESKOM (124.35mtpa), synthetic fuels - SASOL (44mtpa), industries (9mtpa), merchants (12.25mtpa) and exports (57.9mtpa) (Prevost 2008:7).

Graph 2-5 illustrates the South African coal market distribution in 2009.

Graph 2-5 South African Coal Market Distribution in Tons, 2009



Source: (DMR 2009: 48)

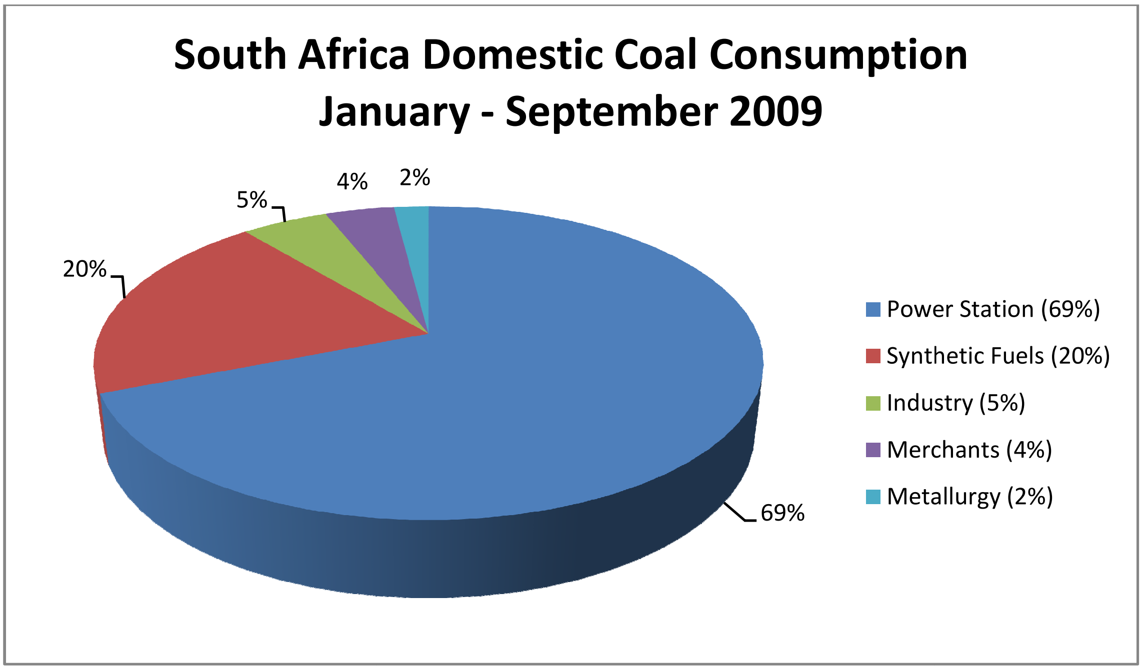
Graph 2-5 shows the South African coal market distribution - the total production for 2009 in tonnage. ESKOM received most of the coal 124.35 Mt (49.37 percent) followed by export 57.9 Mt (23.75 percent). The synthetic fuels industry (SASOL) was the third consumer 44 Mt (17.45 percent). The other coal users were: merchants 12.25 Mt (4.75 percent), industries 9Mt (3.56 percent) and metallurgical (coking coal) 5.7 Mt (2.26 percent) (DMR 2009: 48).

It is estimated that in the next decade South Africa will increase its annual coal production by 75 million tons. It is also predicted that at some point coal production will stagnate and will not be able to meet the energy demand, requiring the country to seek additional supply from nuclear, renewable sources and from the neighbouring countries (Lok 2009: 22).

2.5.3 South African coal consumption

Graph 2-6 shows the South African domestic coal market consumption during January - September 2009.

Graph 2-6- South African Domestic Coal Market Consumption, January-September 2009



Source: (Prevost 2009: 9)

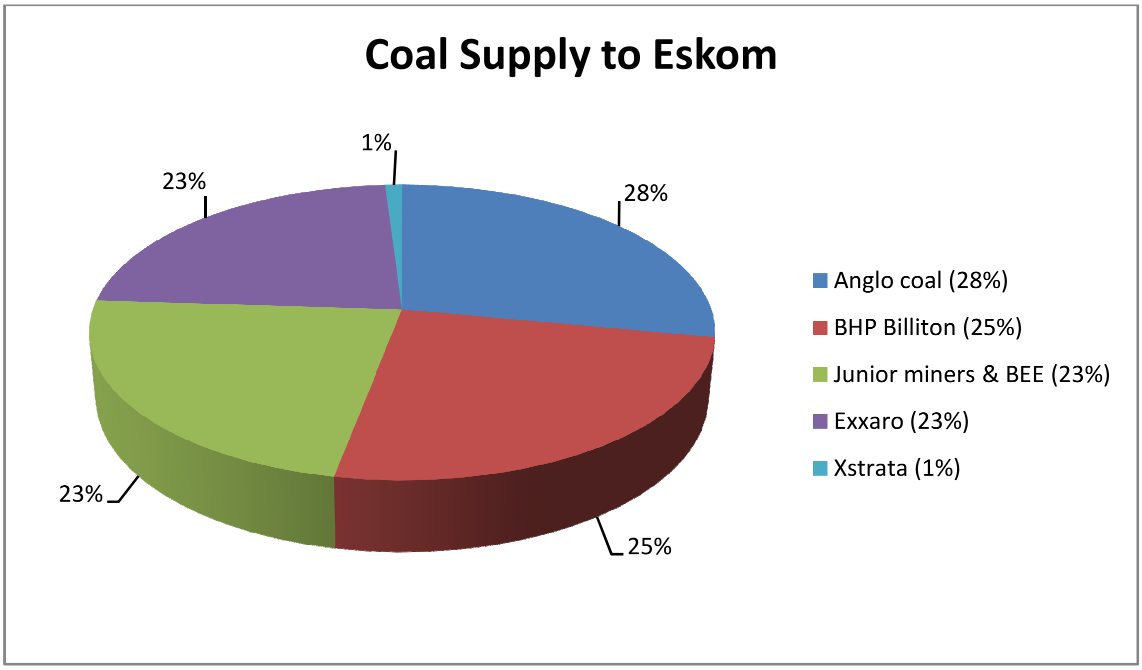
Between January and September 2009 the South African coal consumption by industry was estimated as follows: power generation 69 percent, synthetic fuels 20 percent, industry 5 percent, merchants 4 percent and metallurgy industry 2 percent (Prevost 2009:9). During that period, ESKOM consumed 69 percent, SASOL 20 percent, general industries (5 percent), merchants (4 percent) and metallurgy (2 percent).

ESKOM generates 88 percent of the country's total power generation from coal and it is distributed to approximately 4.5 million customers throughout the country (ESKOM 2009: iii).

In 2009 ESKOM received coal supplies in the following proportions: Anglo America 28 percent, BHP Billiton 25 percent, Exxaro 23 percent, Xstrata 1 percent and Black Economic Empowerment companies 23 percent (ESKOM 2009:9).

Graph 2-7 describes the coal supply to ESKOM by company. The smaller coal mining companies are referred to as junior miners.

Graph 2-7 Coal Supply to ESKOM by Company, 2007



Source: ESKOM, (PED 2009: 9)

Graph 2-7 indicates that Anglo Coal is the leading coal supplier to ESKOM (28 percent) followed by BHP Billiton (25 percent) and Exxaro is the third largest supplier (23 percent). The smaller miners in partnership with Black Economic Empowerment companies supply (23 percent) and Xstrata is presently supplying (1 percent).

In the last 10 years ESKOM's coal consumption has not changed much, which is one of the reasons the country has been experiencing power shortages. Indeed, there were no new huge power plants built in that period. The two new coal-fired power plants Medupi and Kusile will only come on stream around 2013 (ESKOM 2009: 59).

Table 2-2 shows the coal consumption by ESKOM coal-fired power plants for ten years 1999–2008.

Table 2-2 Coal Consumption by ESKOM 1999-2008

Year	Million tons(Mt)
1999	94.86
2000	95.19
2001	91.73
2002	92.62
2003	104.08
2004	110.98
2005	106.30
2006	108.75
2007	112.17
2008	126.07

Source: ESKOM, (PED 2009: 10)

Table 2-2 shows an almost uniform coal consumption rates in the 1999-2002 period. The consumption increased slightly in the 2003-2006 period. The period from 2007 indicates the beginning of steep increase of consumption from 112.17 Mt in 2007 to 126.07 Mt in 2008. This was the period when the country started experiencing power black-outs, which has changed the South African future power demands triggering a massive electricity tariff hike aimed at meeting the future electricity supply capacity.

ESKOM's projection for the country's coal demand for the next ten years is approximately 374 million tons from the estimated national coal production of 270 million ton in 2008. The estimate was based on increase by all segments using coal in the country, including export. This means that the new power plants coming on stream will be supplied by a combination of existing coal mines and the upcoming new coal mines. The domestic market comprises the present and future energy demand for ESKOM, synthetic fuel industry (SASOL) and the requirements by the other industries, which include metallurgy and merchants (ESKOM 2009:13).

Table 2-3 shows the 2008 estimated national coal production and usage and a ten years projection to 2018.

Table 2-3 South African Thermal Coal Consumption in 2008 and 10 Years projection to 2018 (Million Tons)

	2008 (Million tons)	**2018 (Projection) (Million tons)**
1. ESKOM	129	200
2. Export	75	91
3. Sasol	47	64
4. Others (Industry, metallurgy & merchants)	19	19
TOTAL	**270**	**374**

Source: ESKOM, PED (2009:13)

Thermal coal refers to hard coal (bituminous and sub-bituminous) used mainly for power generation and anthracite used as coking coal in the metallurgical industry.

Table 2-3 shows the South African estimated production capacity in 2008 (270 Mt) and a ten years projection to 2018. The actual national coal production in 2008 was 252.2mt. The projection is based on every coal consuming segment. The projection shows ESKOM's demand rising by approximately 55 percent of the 2008 base while the overall country demand would be approximately 40 percent (ESKOM 2009:13).

ESKOM has planned for 40 new coal mines costing about R100 billion that need to be built to provide a sustainable coal supply to the existing power stations and the new ones that are planned to come on stream in the short and medium-term. Most of the current tied-collieries (Coal mine tied to a specific power plant) supplying coal to the power stations were funded by ESKOM or built on cost-plus-contract basis. The future coal-fired power plants will be expensive, costing about R120 billion each which might force ESKOM not to further finance the coal mines, and just contract to buy coal from the mines (Wilhelm 2009: 7-9). Wilhelm (2009:6) notes that capacity building requires skills and estimates that building 40 coal mines would require 600 engineers and 2500 artisans and one of the constraints facing the industry is skills shortage.

2.5.4 South African coal trade

South African coal exports have grown significantly ever since the idea of exporting coal to Europe was first considered in the 1960s. The country's first coal export was 12mtpa in 1976 and the volumes have progressively increased since then. The South African coal export figure in 2007 was 67.7 million tons making it the 5th largest global exporter with a global export contribution of 7.38 percent. The other leading global coal exporters are: Australia 243.6mtpa (26.56 percent), Indonesia 202.7mtpa (22.1 percent), Russia 88.1mtpa (9.6 percent) and Colombia 77.1mtpa (8.4 percent). The total world coal trade in 2007 was 917.3 million tons which was an increase of 6 percent over 2006 (Robinson *et al*. 2008: 43).

Coal is not a uniform commodity as it is marketed in various qualities depending on use, for example the ESKOM grade coal for power generation, coking coal for use in metallurgy for steel making, high quality grade anthracite and so on (Wilhelm 2009: 6). The South African coal trade is dominated by the five leading coal mining companies (Anglo Coal, BHP Billiton, Exxaro, SASOL and Xstrata) amounting to 83 percent of the South African coal trade. The rest 17 percent of coal trade is by the Black Economic Empowerment companies which emerged after the Mining and Petroleum Resources Development Act (MPRDA) Act of 2002 (Prevost 2009:7).

Due to its necessity as a fuel for the generation of electricity and other commercial usage in the world, coal is a highly traded commodity. Besides being the primary source of electricity in South Africa, coal is also converted into liquid through the Fischer-Tropsch process by SASOL to produce liquid fuel (synthetic fuel), providing the country with a third of the liquid fuel requirements (Molteno 2008:189). Its price has risen from 30 US dollars per ton in 2000 to around 123.50 US dollars per ton in June, 2008. Despite the global commodity boom in coal trade, the South African coal mining sector experienced a decline in exports of 6.3 percent exporting only 63.7 million tons in 2008. The decline was mainly due to lower coal transportation (rail), inadequate rolling stock and operational constraints, all attributed to TRANSNET. The other causes of decline in coal trade included production shortages (permits and rain problems) and the diversion of some export quality coal back to ESKOM in order to improve power station depleted stock levels. Therefore, domestic coal trade consumed part of the export coal in 2008 (Chamber of Mines 2008:18).

The Intercontinental Exchange (ICE) coal trade has Rotterdam as the centre for Europe and Richards Bay for South Africa as trading coal terminals. Coal is traded in either contracts or spot prices in United States dollars (USD) in units of 5 000 tons. The Richards Bay Coal Terminal handling capacity has been 72Mtpa (Goussard 2009: 9) and has presently reached 91Mtpa in 2010 (Prevost 2010: 6). The average Richards Bay Free on Board (FOB) price of coal exported in 2007 was USD 68.17 per ton. However, the coal export price volatility during the year resulted in an improved price of USD 145.76 per ton by September 2008. South Africa exported to 34 countries in Europe in 2007 and the leading buyers were Great Britain, Spain, France, Italy and Germany (Robinson *et al.* 2008:46).

Table 2-4 shows South Africa's production and sale of coal in the period of 1999-2008.

Table 2-4 South Africa's Production and Sale of Coal, 1999-2008

		LOCAL SALES			**EXPORT SALES**		
YEAR	**PRODUCTION**	**Mass**	**Free On Rail (FOR)**		**Mass**	**Free On Board (FOB)**	
	Million ton (Mt)	**Mt**	**R'000**	**R/t**	**Mt**	**R'000**	**R/t**
1999	222,3	154,6	8 305 568	53	66,2	9 234 328	142
2000	224,1	154,6	8 772 310	57	69,9	11 185 460	160
2001	223,5	152,2	9 564 521	63	69,2	16 956 659	245
2002	220,2	157,6	11 773 123	75	69,2	19 366 998	280
2003	239,3	168,0	13 212 837	79	71,5	13 490 623	189
2004	242,8	178,3	13 606 151	76	67,9	14 472 904	213
2005	245,0	173,4	14 878 140	86	71,4	21 155 176	296
2006	244,8	177,0	16 245 861	92	68,7	21 745 322	316
2007	247,7	182,8	19 718 642	108	67,7	24 447 656	361
2008	252,2	197,1	30 119 929	153	57,9	42 447 656	732

Source: DMR (2009: 46)

Table 2-4 shows the coal trade in South Africa for a ten year period, 1999-2008. It includes coal production in the ten years, for domestic and export markets with their respective prices. The production appears almost constant as there were very little variations between the years. For instance, in 1999 production was 222.3 Mt and in 2008 it was 252.2 Mt. There is little variation in the local prices, but export prices indicate a huge variation in the two years, 2007 (R 361/t) and 2008 (R 732/t).

The local coal price per ton FOR (Free on Rail) averaged R 150.40 per ton in 2008, a 40.5 percent increase on the 2007 price. The average export price FOB (Free on Board) was R 704.62 per ton in 2008, a 94.5 increase over the 2007 price. The rise in local price was mainly attributed to higher mining costs resulting from higher input costs. The price of coal used in the domestic electricity sector increased by 25.7 percent averaging R 111.82 per ton in 2008 and for the first three months of 2009, the price rose by 10.6 percent to R 123.66 per ton FOR.

The price of coal used for the production of synthetic fuels averaged R 127.51in 2008, an increase of 15.3 percent year-on-year and rose by another 15.5 percent to R 147.25 per ton FOR in the first three months of 2009. The metallurgical coal price in 2008 averaged R770 per ton and the coal sold to the small consumer market was sold at R 341 per ton (Chamber of Mines 2009:28).

Table 2-5 shows domestic and export coal price variations in South Africa in 2008.

Table2-5 Domestic and Export Price of Coal, 2008

Category	**Price (domestic & export)**
	Rand/ton (R/t)
1.Supply to Eskom	R111.82 (FOR)
2.Sasol	R127.51(FOR)
3.Mettallurgical coal	R770(FOR)
4.Traders	R150.40(FOR)
5.Small consumers	R341.00(FOR)
6.Export	R704.62(FOB)

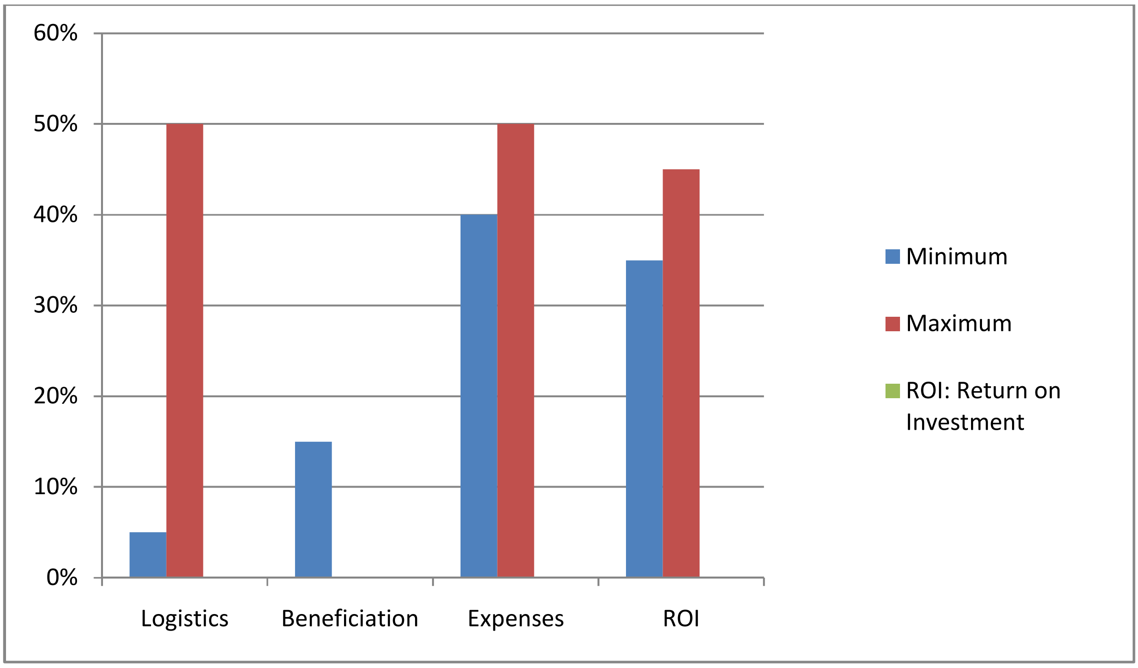
Source: Chamber of Mines (2009: 24)

Table 2-5 shows how coal was traded in South Africa in 2008. The supply price to Eskom was the lowest (R 111.82/t FOR) followed by Sasol (R127.51/t FOR). Traders who bought coal in bulk received better prices (R 150.40/t FOR) compared with the small consumers who bought at R 341.00/t. The export price in 2008 was R704.62 FOB/t (Chamber of Mines 2009:28).

The cost drivers for coal include logistics (transportation), washing of coal (beneficiation), operational (administration and salaries) and others. In South Africa, the major cost drivers in mining as a percentage of delivered cost are logistics (5-50 percent); beneficiation (0-15 percent); capital redemption and return on investment (35-45 percent) and run of mine operating expenses (40-50 percent) (ESKOM 2009:29).

Graph 2-8 elaborates the major cost drives in the coal mining industry.

Graph 2-8 Major Cost Drivers in Mining



Source: ESKOM, (PED 2009: 29)

Graph 2-8 shows that coal mining's leading expenses are in logistics and general expenses.

In the coal mining industry, logistics mainly refers to outbound logistics (transporting coal from the mine stockpiles to the customers' stockpiles and export terminal stockpiles for export coal. Beneficiation entails cleaning of coal by removing the compounds of nitrogen/ sulphur and waste substances (discarded poor quality coal). The process uses a large volume of water. Expenses refer to all costs incurred in the coal-mining process (administration, wages, taxation, transportation and others). Return on investment refers to profitability of the operations.

2.6 THE KEY ROLE PLAYERS IN THE SOUTH AFRICAN COAL-MINING INDUSTRY SUPPLY CHAIN

The key role players in the South African coal-mining industry supply chain comprise mining companies, government departments responsible for minerals and environmental affairs, domestic and export coal customers, rail logistics company TRANSNET, the main coal export terminal at Richards Bay and the Chamber of Mines of South Africa. The critical roles played by the leading domestic customers/consumers (ESKOM and SASOL) and export coal are emphasised.

2.6.1 South African coal mines

The South African coal mines are mainly situated in the coalfields of Mpumalanga, Free State, Limpopo, and Kwa-Zulu Natal with Mpumalanga as the leading coal producer in the country as stated above.. The leading coalfields in Mpumalanga are Witbank and Highveld (Prevost 2009:6-7). The coal mining industry commenced commercial mining in 1885 and the cumulative coal mined since 1885 to 2006 was 6.982 billion tons (DME 2009:52). As of 2007, there were 73 collieries in the country distributed as: Mpumalanga 61, Kwa-Zulu Natal 7, Free State 2 and Gauteng 1 (DME 2007:44).

The two methods of mining used in South Africa are opencast and underground methods. Opencast mining (surface mining) is applicable when the coal seam is close enough to the earth’s surface. The process involves removing the earth (overburden) which covers the coal seam and then blasting the seam to remove the coal. The equipment used includes draglines, shovels, front-end-loaders, bucket-wheel excavators and trucks. The overburden removed is kept separately then returned back to the mine after coal has been extracted (Lloyd 2002:1-4**).**

The opencast mining is favoured over the underground mining due to its higher output. Opencast is simple and comprises truck, shovel and dragline. The underground mining comprises board and pillar, short-wall and long-wall mining methods (Bloy 2005: 37). The underground coal gasification is another method of coal mining whereby, raw coal underground is converted into a combustible gas that can be used for industrial heating, power generation, manufacturing of hydrogen, synthetic natural gas or other chemicals (Roods 2009: 7).

The largest mine in South Africa is Grootegeluk in the Waterberg coalfield in Limpopo Province. It is an opencast mine. After a few metres of overburden, primary coal of about 80 metres thick is found distributed in thin seams separated by shale and stones. Ten metres or so of solid rocks separates the secondary coal found in bands of several metres. The coal and rock ratio in this mine is 1:1 (50 percent coal and 50 percent rocks). Grootegeluk is the world's lowest-cost producer with the most efficient coal mining operations and the largest beneficiation mine (Exxaro 2007:6). The mine produces 17.4Mtpa of saleable coal which is broken down as follows: 14Mtpa supplied to Matimba coal-fired power station, 2Mtpa supplied to the metallurgy industry as coking coal and 1.4Mtpa for export. The mine's overburden is in equal ratio to the saleable coal. Hence, 50 percent of excavation goes to waste (Fauconnier 2005: 2).

Underground mining involves the construction of shafts to extract coal which is too deep to mine from the surface (Anglo Coal 2007:47). Underground mining occurs where coal seams are too deep, usually over 40 metres deep. The average depth of underground mines in South Africa is about 80 metres which is considered shallow by world standards. The overburden is removed and kept separately. The square "rooms" about 10 metres wide supported with pillars are made to hold the roof as the coal extraction process takes place underground. After extraction of coal the roof is allowed to collapse behind the mined out area. This process of underground mining is known as long-wall mining and comprises about 5 percent of coal mining in South Africa (Lloyd 2002:1-4).
The types of coal produced in South Africa include lignite, sub-bituminous and bituminous coal, anthracite and graphite. Lignite, sub-bituminous and bituminous coals

are used in the power stations for electricity generation and export while the higher quality anthracite and graphite are used as coking coal in metallurgy and for export. Coal beneficiation is done for export due to the higher quality required (DME 2007:44). The three coalfields in Mpumalanga (Highveld, Witbank and Ermelo) presently produce over 80 percent of the South African coal. The highest coal grade anthracite and coking coal from Kwa-Zulu Natal have largely been depleted (Prevost 2009: 6).

A report from ESKOM indicates that mining development has stalled in the last four years. It also indicates a projection up to 2018 comprising 43 new mines at an estimated cost of about R 100 billion and raising the 2008 national production estimate of 270mtpa to 370mtpa by 2018. Those mines would be developed by the existing leading mining groups in the industry and just a few to be developed by the Black Economic Empowerment companies (ESKOM 2009: 15).

2.6.2 Department of Mineral Resources (DMR)

The Department of Mineral Resources (DMR), previously Department of Minerals and Energy (DME), has provided the Mineral and Petroleum Resources Development Act – Act 2002 (Act No. 28 of 2002) that was promulgated in April 2004. The Act provides guidelines to the South African mining industry. The relevant extract from the Act is stated in the Government Gazette of 2002 which is stipulated in the later part of this chapter (section 2.8.1).

2.6.3 National Energy Regulator of South Africa (NERSA)

The National Energy Regulator was established in October 2005 to regulate the energy sectors in electricity, piped gas and petroleum. Prior to 2005 it was called the National Energy Regulator (NER) responsible for regulating the electricity-related industry only. It is actually this role of regulating electricity that is of concern in this research as it relates to the fuel used (coal) in the generation of electricity (NERSA 2009: 5). In addition to the regulation of electricity, NERSA regulates the petroleum pipeline and piped gas including coal bed methane (CBM) (CMM Global Overview 2008:203).

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).

The energy regulator also has a programme of issuing and monitoring licenses to independent power producers (IPPs) which has been mandated to generate electricity from renewable sources sold to ESKOM for inclusion to the national grid. The programme is called Renewable Energy Feed-In Tariff (REFIT) (NERSA 2009: 11).

2.6.4 ESKOM

ESKOM is a South African government-owned power utility company that consumes the bulk of coal produced in the country as fuel for the generation of electricity through its current 13 coal-fired power plants which generate about 88 per cent of the national electricity (ESKOM 2009: 226). ESKOM is one of the top 10 utilities in the world by generation capacity (ESKOM 2009: iii). This is an indication of the size and capacity of the utility. The company's electricity generation mix comprises coal, hydro, pumped storage and some imports. This brings the total nominal capacity to 44 193 megawatts (MW) (ESKOM 2009: iii).

ESKOM consumes approximately 50 percent of the coal produced in South Africa and approximately 66 percent of the total domestic coal consumption. Its consumption in

2008 was 128.07 million tons of coal out of the national production of 252.2 million tons (DMR 2009:47).
The power crisis of 2007/2008 impacted heavily on the company and on the economy as well as communities. The coal stockpile at the power stations had deteriorated due to poor coal logistics, among other factors. As a result, ESKOM was forced to step up coal transport by road to the detriment of the environment in the Mpumalanga area where most of the coal-fired stations are located (Bischoff 2009: 100).

Due to the growing energy demand, Camden power station, which was mothballed for twenty years, was re-commissioned to contribute towards the rising power demand (Lang 2009: 1).The five largest mining companies in South Africa supply 77 percent of ESKOM's coal demand and the remaining 23 percent is supplied by the smaller mining companies (Junior miners) in partnership with Black Economic Empowerment (BEE) mining companies (ESKOM 2009:9).

This study also established during the interviews that coal transportation is done 70 percent by conveyor belts, 24 percent by road and 6 percent by rail. The future plan is to reduce road transport to below 6 percent and increase rail transport to more than 24 percent. ESKOM is under pressure to control costs and rail transport is viewed as being more economical, safer and sustainable.

2.6.5 TRANSNET

'TRANSNET is a South African government-owned corporation which is the operator and custodian of South Africa's major transport infrastructure (rail, harbours and pipelines). The entity ensures that the country's freight transportation system operates according to world-class standards and as an integral part of the overall economy.' (TRANSNET 2009:2).

'TRANSNET is featured as one of the most important logistics companies in the coal industry. The railway service is predominantly used to transport export coal to the

Richards Bay Coal Terminal, a distance of approximately 650 kilometres from Mpumalanga coalfields. It also transports some coal to the ESKOM power plants.' (TRANSNET 2008:136).

'TRANSNET is in the ESKOM plan of delivering coal to the power stations in the Mpumalanga region as a way of streamlining coal supplies to the power stations in future. This is due to the environmental damages experienced in transportation of coal by road' (Bischoff 2009: 101). The rail line to Richards Bay Coal Terminal has a capacity of 74Mtpa plus 10Mtpa to the other smaller terminals, adding up to 84Mtpa (Wilhelm 2009: 8).

Its business unit, TRANSNET FREIGHT RAIL (TFR), is responsible for rail freight. The main focus of TFR is transporting bulk and containerised freight. During the 2007/2008 period, the division transported 179.9 million tons of freight for export and domestic customers, (TRANSNET 2008:10). This figure went down during 2008/2009 to approximately 177 million tons (TRANSNET 2009: 2). The total coal transported in 2008 was 67 million tons (TRANSNET 2008:97). Other coal shipments by Transnet were: 2005 (71.4 Mt), 2006 (68.7 Mt) and 2007 (67.7 Mt) (DMR 2009: 46).
Table 2-6 shows Transnet coal shipment for four years, 2005-2008.

Table 2-6 Coal Shipment by Transnet 2005-2008

Year	Freight (Mt)
2005	71.4Mt
2006	68.7Mt
2007	67.7Mt
2008	67.0Mt

Source: (DMR 2009: 46)

Table 2-6 shows a decline of coal shipment by TRANSNET during the period of 2005-2008. This is an indication of constraints within the coal supply chain at the mine, with Transnet services or with the customer.

In order to enhance its services to customers, TRANSNET (2008:101) had set objectives which includes:

- commissioning of 110 new electric locomotives for the coal export line in the 2008/2009 period;
- improving on weekly shipment of coal. The weekly shipment of coal in 2007 was 1.445 million tons;
- focusing on implementation of efficient improvements on 'a scheduled railway' on key corridors- the export lines and the Gauteng/Durban corridor;
- improving throughput and enhancing schedule adherence;
- implementing the integrated asset-tracking system (IATS) at the national operations centre (NOC). The objective for the system was to enable the real-time tracking of rolling stock, to ensure visibility of operations at the NOC and ultimately to improve customer service; and
- planning capital expenditure for coal line services during the next five years was set at R 6.5 billion.

According to TRANSNET (2009:12), the key projects executed in the 2008/2009 period on the rail side included:

- expansion of the iron ore and coal export line;
- acquisition of 204 locomotives for deployment on the coal, iron ore and general freight line; and
- upgrading of rolling stock and infrastructure for general freight business.

The coal line capacity expansion is intended to increase capacity of coal exports to above 71 Million tons per annum (Mtpa). The project included an upgrade of locomotives; repair and upgrading of wagons; upgrading of running rail lines; improvement in infrastructure; the upgrading of signalling and the provision of a platform for further future expansions (TRANSNET 2009:114). The TFR attributed the loss of freight volume and revenue in 2007/2008 to inadequate and interrupted power supply by ESKOM, culminating in the customers' production losses due to power-supply disruptions. However, TFR is in constant dialogue with ESKOM to ensure minimal disruptions to rail traffic in key corridors (TRANSNET 2008:99).

According to Prevost (2010:17), the 2009 export coal slumped to 61.1Mtpa due to TRANSNET's capacity being below that of RBCT. However, TRANSNET has eventually launched the "Quantum Leap Project" to raise the rail capacity to 81Mtpa and it is also planning a "Beyond the 81Mtpa Project". This positive development was motivated by coal export forecasts that India will need to import 110 million tons of coal from 2012 and 25 million tons would come from South Africa.

Table 2-7 shows the monthly coal shipment by Transnet Freight Rail year to-date January to November 2009.

Table 2-7 Transnet Freight Rail's (TFR) Operating Statistics, 2009

Date	TFR Railings Million tons (Mt)	Year To Date	Annualised Monthly Rate Million tons per annum (Mtpa)	Number of Trains
Jan-09	4.96	4.96	59.52	**684**
Feb-09	5.32	10.28	61.68	**651**
Mar-09	5.19	15.47	61.68	**811**
Apr-09	5.27	20.74	62.22	**678**
May-09	3.86	24.60	59.04	**607**
Jun-09	5.25	29.85	59.70	**680**
Jul-09	5.10	34.95	59.92	**606**
Aug-09	5.35	40.30	60.45	**793**
Sep-09	4.99	45.29	60.39	**672**
Oct-09	5.29	50.58	60.70	**789**
Nov-09	5.26	55.84	60.92	**653**
TOTAL	**50.84**			**7624**

Source: Richards Bay Coal Terminal (RBCT), 2009: 3

Table 2-7 shows the operations statistics by TRANSNET Freight Rail for the 11 months of 2009. The total freight for the 11 months was 50.84 million tons. The Year-to-date column shows the cumulative freight after each month. The annualised monthly rate shows freight for one year at the given month of 2009 (for example, February 2008 to February 2009 equals 61.68 Mt). The last column shows the number of train shipments per month cumulative for 11 months in 2009. At that rate of transportation, it was predicted that the outcome for 2009 would be much lower than the figures for 2008, which was 76 million tons (DMR 2009:46). This could be attributable to the impact of the economic slowdown in 2009 and other supply-chain constraints.

2.6.6 Richards Bay Coal Terminal (RBCT)

The port of Richards Bay is situated 170 kilometres north of Durban on the Indian ocean coastline. It was opened in 1976 and commenced with an export capacity of 10Mtpa. This capacity grew over the years and reached a capacity of 72Mtpa on completion of eleven caissons by 2008 (Goussard 2009:8).

Richards Bay Coal Terminal (RBCT) is the largest single coal export terminal in the world, exporting more than 69 million tons annually. The port's export handling capacity in 2009 was 76mtpa and this reached 91mtpa in 2010 (Prevost 2009:7). The port is owned by 11 coal mining companies with the five leading mining companies Anglo Coal, BHP Billiton, Xstrata, Exxaro and Sasol owning most of the shares (DMR 2009:47).
The RBCT set a new world record in September 2006 by loading and exporting 409 809 tons of coal in a 24-hour period. The port has also grown into a 24-hour operation with export capacity of 68Mtpa in 2006 and reaching 91Mtpa, as pointed out above, in 2010 (Prevost 2009:7).

The expansion of the port is in preparation for accommodating future coal export growth and servicing of the emerging black economic empowerment (BEE) coal mines. Presently, the BEE coal mining companies are allocated 4 million tons per annum (DMR 2009:47).

'With five berths and four ship loaders RBCT is linked by TRANSNET's 650 kilometres rail line with the coalfields in Mpumalanga for export coal. At inception in 1976, the rail had trains with 50 wagons carrying 3 742 tons of export coal and by 1996 the rail line had become a world-class rail system. It presently moves 2.5 kilometres_long trains with 200 wagons carrying up to 17 000 tons of coal to the Richards Bay coal terminal. The terminal has a storage capacity of 6.7 million tons of coal that is serviced by 6 stacker reclaimers, two stackers and a reclaimer. The port also co-ordinates the arrival and departure of ships with the National Ports Authority with about 700 ships accounted for per annum' (Coal International 2007:12).

Table 2-8 shows Richards Bay Coal Terminal operating statistics in 2009

Table 2-8 Richards Bay Coal Terminal (RBCT) Operating Statistics, 2009

Date	**RBCT – Loadings (Million tons) Mt**	**Year To Date (Million tons)**	**Annualised Monthly Rate (Million tons per annum) Mtpa**	**Number of ships Loaded**
Jan-09	4.1	4.1	49.1	**44**
Feb-09	5.2	9.3	55.9	**58**
Mar-09	4.9	14.2	56.6	**58**
Apr-09	4.6	18.7	56.1	**62**
May-09	3.8	22.5	53.9	**48**
Jun-09	5.5	28.0	56.0	**73**
Jul-09	5.4	33.4	57.3	**72**
Aug-09	5.6	39.0	58.5	**70**
Sep-09	4.2	43.2	57.6	**54**
Oct-09	6.8	49.9	59.9	**81**
Nov-09	5.6	55.6	60.6	**61**
TOTAL	**55.56**			**681**

Source: Richards Bay Coal Terminal (RBCT), 2009: 4

Table 2-8 provides a coal loading profile at the Richards Bay Coal Terminal (RBCT) per month and cumulative tons loaded in the 11 recorded months of 2009 in the second column. The third column is the cumulative monthly total tonnage of coal loaded into the ships. The fourth column shows the annualised rate of loading coal into the ships (that is the number of tons loaded in a year as at that respective month). The right hand side column shows the number of ships loaded at the RBCT terminal per month January to November 2009 and the cumulative number of ships loaded.

2.6.7 SASOL

South African Synthetic Oils (SASOL) is a South African public company founded in 1950 and is listed on both the Johannesburg stock exchange (JSE) and New York Stock Exchange (NYSE). The company supplies a third of South Africa's liquid fuel requirements. Sasol is one of the top six companies on the JSE and South Africa's largest locally domiciled company. It is also the country's single largest industrial investor, as well as the largest chemical feedstock producer. Its contribution to the Growth Domestic Product (GDP) is 4.7 percent amounting to R 40 billion a year (SASOL 2008:69-70).

Table 2-9 shows how Sasol uses coal that it produces.

Table 2-9 Use of Coal Produced by Sasol, 2009

Usage	Million tons
Synthetic fuel	39.0
Own power generation/ Steam production	2.0
Export	3.9
Supply to Eskom	0.3
	46.0

Source: (SASOL 2008:12)

Table 2-9 shows SASOL's coal production in 2008 which was approximately 46 million tons (Mt) comprising 22 percent of the national coal production. The company used the bulk of it (39 Mt) for synthetic fuel production, (3.9 Mt) export to Europe for power generation, about 2 Mt for its own electricity and steam production while 0, 3 Mt was supplied to ESKOM. SASOL commenced export business in 1996 after acquiring a 5 percent stake in the Richards Bay Coal Terminal (RBCT) (SASOL 2008:12).

‘The company made the first petrol from coal from SASOL1 plant built in 1955 at Sasolburg. The events of the world oil hike in 1973 motivated the company to step up its coal production capacity to boost production of synthetic fuels. As a result, SASOL 2 and SASOL 3 plants were built in 1979 in Secunda as the trade embargo on apartheid South Africa became imminent (Lang 1995:182). The company began producing synthetic gas from coal and importing natural gas from Mozambique in 2005. That was before the establishment of NERSA. However, SASOL negotiated the regulatory agreement that is now honoured by NERSA. The agreement is a public document and guarantees SASOL licenses for its distribution areas, subject to certain conditions as stipulated by NERSA.’ (CMM Global Overview 2009: 203).

‘SASOL’s primary business is based on CTL and GTL technology using Fischer-Tropsch synthesis. CTL and GTL plants convert coal and natural gas respectively into liquid fuels. SASOL developed a GTL project in Qatar in 2006/2007 and is developing one in Nigeria that will be commissioned in 2011. It is presently also conducting feasibility studies relating to potential CTL plants in China. However, the only problem with the use of the Fischer-Tropsch synthesis is the massive emission of carbon dioxide into the atmosphere. Indeed, the company’s Secunda plant is one of the world’s single largest emitter of carbon dioxide.’ (SASOL 2008: 83).

‘SASOL has plans to build a giant CTL plant called the ‘Mafutha Project’ in the north-western part of Limpopo in the Waterberg coalfields. The project would provide 40 percent of South Africa’s liquid fuels, have a capacity of 80 000 barrels per day, consume about 25 million tons of coal per year, which is estimated to cost about USD 16 billion (R124 billion).’ (Brown 2009(b):3).

2.7 THE SOUTH AFRICAN COAL MINING BUSINESS MODEL

Figure 2-1 shows a South African coal mine business model indicating the downstream stages involved up to delivery to the customers.

Figure 2-1 The South African Coal Mining Business Model

Source		Distribution (Transport Mode)	Customers
Coal Mine	Stockpile	Conveyor	-Power Station -Sasol
		Road	-Power Station -Sasol -Industry
		Rail	-Power Station -Traders -Export(RBCT)

Source: Own model

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

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.

Stage 2: Distribution (Transportation)

Three types of transport modes are used for local distribution depending on the type of customer (conveyor, rail and road) and ship 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. 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, coal for other industries and for traders is delivered by road and rail.

Stage 3: Customers

The customers for coal are the power stations, SASOL, industry, traders and it is exported to the power stations abroad and to the metallurgical industry..

SASOL: mines its own coal supply from its mines in Secunda and coal is mainly supplied to the conversion plant via conveyor belt and road where mines are far from the processing plant.

Power stations: approximately 70 percent of the coal burned at the power stations is transported via conveyor belts since most of the power stations are built next to the coal mines. The rest of the coal is supplied by road (24 percent) and rail (6 percent). Road and rail transport are used to supply those mines that do not have mines next to them or those mines that do not receive enough supply from their designated coal mines. ESKOM hopes to increase the rail transport to over 24 percent in future when Transnet is in a position to meet their demand since rail transportation is more economical, convenient and sustainable (ESKOM 2009:2).

Coal export**:** presently most of the export coal originates from the Mpumalanga coalfields and it is transported to Richards Bay Coal Terminal (RBCT) by rail, a distance of about 650 kilometres. The service is provided by TRANSNET through its business unit Transnet Freight Rail (TFR).

The South African coal mining business model is simple as it involves mining including beneficiation, stockpiling and distribution to the end users/consumers. Therefore, constraints may be tracked from operations, human capacity (skills), transport logistics and legislation as gathered from the field interview report.

2.8 THE TREND IN COAL MINING GLOBALLY

Despite the global environmental concerns attributed to the use of coal as a primary source of energy, the demand for coal continues to rise. ‘The energy demand in the developed countries of European Union and North America the rapid development of the Asian countries like (Japan, China, India and South Korea) among others will keep the coal demand high for some years’ (Ekawan & Duchene 2006:1494).

The infrastructure backlogs in many globally advanced economies continue to constrain the energy supply chain and it is hoped that the situation will improve when the infrastructure rises as a proportion of GDP to support the energy demand. ‘During the 2007/2008 coal supply boom, the six Ps (power, people, permits, procurement, projects and politics) were constraining factors on energy supply.
However, despite its adverse impact on the environment the future of the coal mining industry looks bright. This will seemingly remain the case until such time that renewable energy sources become economically feasible, aided by nuclear power to provide clean energy. Individual countries have varying plans to meet their future energy requirements.’ (Chamber of Mines 2009:11).

Coal mining in the world is on the increase due to the continuous energy demand to meet the pace of economic development and urbanisation. However, the issue of carbon emissions will lead the coal industry to transform to new clean coal technologies (CCT). ‘The United States is looking at the future transformation of the conventional pulverised coal burnt at the power stations for power generation to integrated gasification combined cycle (IGCC) power plants and the use of additional amounts of coal to produce hydrogen for fuel-cell vehicles. It is estimated that the IGCC power plants can significantly reduce U.S coal consumption and transportation demand by about 400mtpa. Hence, widespread gasification for electricity production has the potential to open the door for hydrogen production.’ (McCollum & Ogden 2009: 460-471).

In China, coal provides about 58 percent of the total primary energy demand. The rest is realised from renewable and nuclear sources.' (Asif & Muneer 2007:1403-1404). 'It is estimated that about 1.4 million more people will become urbanised over the next two decades, with 300 million in China alone. In order to meet the anticipated increase for electricity demand, China is expected to build another 500 new coal-fired power stations.' (Chamber of Mines 2009:25). 'The Chinese coalfields in Mongolia have the world's best performing mines using the best and the most highly productive equipment for deep coal mining.' (Flook & Leeming 2006: 26-27).

'In India coal dominates the energy mix in meeting about 60 percent of the total energy requirements in the country. India is the 6th largest energy consumer in the world and also accounts for 3.5 percent of total world primary energy consumption and 12 percent of the Asia-Pacific region. The country has been an importer of coal since 1985. India has the world's third largest coal reserves. However, the country has a huge potential for the use of renewable energy resources since it is estimated that there is over 100 000 MW that will need to be harnessed in a planned and strategic manner to mitigate the gap between demand and supply.' (Asif & Muneer 2007:1406).

In Australia coal mining is developed by the mining companies in a partnership involving the government and the indigenous people in order to protect their cultural heritage, archaeological and sacred sites. 'This partnership is coordinated by Australian Federal Department of Industry, Tourism and Resources in the respective states where coal is mined. The objective of the partnership is to support and encourage the development of long-term, beneficial partnership between mines and the indigenous people.' (Xstrata 2008:31).

Australia is the leading exporter of coal in the world. Since 2006, the country has established an elaborate coal rail infrastructure master plan to support the massive coal export to 2025 and beyond. Most of the Australian coal comes from the states of Queensland and New South Wales. The export coal supply chain is from the coal pit to the ship using three railways and four harbours (Van Der Klauw 2009:12).

2.8.1 The future of coal mining in South Africa

The future of South African coal mining lies in coalfields which were identified in the past, but were never exploited due to constraints such as the lack of infrastructure, difficult coal mining conditions, high ash content and low calorific value (CV). ‘These massive areas include Waterberg, Springbok Flats, Limpopo, Soutpansberg, Tuli, Mabopane, Venda-Pafuri and the Free State coalfields. They contain younger coal compared to that of Mpumalanga coalfields. The Waterberg coalfields alone contain about 3.4 billion tons of coal or 11 percent of South African recoverable coal.’ (Prevost 2008: 6-9)

With the Mpumalanga coalfields being presently overexploited, the future of South African coal production lies in the Waterberg coal fields in the Limpopo Province (Prevost 2010:17). ESKOM plans to construct new power stations in the area in future, commencing with the R110 billion Medupi dry-cooled coal power plants under construction outside Lephalale. The feedstock for the giant power plant of about 14.6 million tons of coal per year will be supplied by the Grootegeluk coal mine owned by Exxaro Resources.

In broader perspective, the utility company ESKOM ‘estimates that about 40 new coal mines will have to come on stream over the next 10-12 years at a cost of between R 90-110 billion. The Grootegeluk coal mine is the only operating colliery on the Waterberg coalfield and presently supplies 14.6mtpa of coal to another giant dry-cooled Matimba power station located in the same area. The contract to supply coal to these giant power plants is for 40 years. Hence, Exxaro has embarked on a massive expansion plan for the Grootegeluk coal mine in order to meet its current and future feedstock supply obligations with ESKOM. Grootegeluk is the largest open-pit mine in the country and produces about 20 percent of the national requirements for the coking and metallurgical coal. It is also the most cost-effective operation and the biggest beneficiation plant in the world.’ (Van Vuuren 2009:12-14).

The availability of water is a significant factor in the coal-mining industry. Large volumes of water are needed for mining, beneficiation and processing purposes (Prevost 2008:11). ‘In the case of the Waterberg coalfield, the availability of water is a major inhibiting factor. ‘The Matimba power station uses water from Makola Dam outside Lephalale. Presently, more water could become available by raising the level of Makola Dam, but it would not be enough for the earmarked development in the area. A geo-hydrology study is also being carried out to establish the availability of water in the area.’ (Van Vuuren 2009:15).

The South African coal mining sector has medium and long-term plans to increase coal production capacity.’Presently, the industry has R15.5 billion worth of projects underway which could yield about 36 Mt of extra coal production, while also sustaining production at some mines. Another 63 Mt worth about R 30 billion is in the final feasibility stage. It is estimated that about R100 billion will be invested in the industry over the next decade if targets are to be achieved.’ (Chamber of Mines 2009:27).

ESKOM has two new coal-fired power plants under construction (Medupi and Kusile) which means new coal mines will be built or the existing ones will be improved to meet the additional capacity when the mines come on stream in the next three years.’ (ESKOM 2009:59). According to Brown (2009:2), the proposed Mafutha liquid fuel plant in Limpopo Province will provide about 40 percent of South Africa’s liquid fuels which will be a great saving in foreign exchange and a boost to the GDP.
The mining operations in South Africa are regulated through the The *Minerals and Petroleum Resources Development Act* (MPRDA) Act 2002 (Act No. 28 of 2002).
According to the (Government Gazette 2002: 3), some of the highlights of the Act include:

- recognition of State custodianship of all mineral resources within the Republic of South Africa;
- promotion of equitable access to the nation’s mineral resources, especially among historically disadvantaged South Africans;

- promotion of investment, growth and employment in the mineral industry thus contributing to the country's economic welfare;
- provision for security of tenure in respect of existing prospecting and mining operations;
- giving effect to section 24 of the Constitution by ensuring that the nation's mineral resources are developed in an orderly and ecologically sustainable manner; and
- ensuring that holders of mining rights contribute towards the socio-economic development of the areas in which they are operating.

Legislation has introduced transformation in the South African mining industry as a whole through the *Broad-based socio-economic empowerment charter for the South African mining industry*. In the coal mining industry, Black Economic Empowerment coal mining companies have grown from 2 in 2002 to 29 in 2008 making a very important contribution to the coal export market (DMR 2009:47).

Most of these BEE coal mining companies are small, but others have established partnerships with large, existing companies. For instance, Exxaro emerged from the merger, in 2006, of former Kumba Resources (Anglo American) and Eyesizwe Coal (black company) to form the biggest empowerment coal-mining company (Exxaro 2007:3).

Until recently, small coal-mining companies have been excluded from using the RBCT's facilities, which were exclusively reserved for the shareholders. However, the government intervention with the RBCT shareholders on behalf of the black coal-mining companies managed to secure a 4mtpa coal export allocation for those companies. One of the reasons for the recent expansion for RBCT's handling capacity to 91mtpa was to accommodate those companies involved in coal exportation. (DMR 2009:47).

2.9 CONCLUSION

This chapter has covered the South African coal mining industry and the industries role players. The background to coal as a product, it's types and uses was also elaborated upon. The world and South African recoverable coal reserves, production, consumption and trade with graphic illustrations and tables were discussed. .

The leading role players in the industry with emphasis on the five leading coal mining companies were described. The roles of ESKOM as the leading consumer of coal for power generation and TRANSNET as the leading rail logistics organisation were highlighted. The role of SASOL in converting coal into liquid fuel and the Richards Bay terminal as the leading export coal terminal were also explored. . The roles of the government Department of Mineral Resources and Department of Environmental Affairs and Tourism in enforcing the mining and environmental legislation respectively were explained.

A South African coal mining business model was provided and the three stages of the coal supply chain described. Coal mining processes which include beneficiation and stockpiling, transportation modes (conveyor, rail and road) and customers (power stations, industry, traders and export) were elaborated upon. The global trend in coal mining which is dictated to by the rising energy demand was noted. The depletion of coal reserves from Mpumalanga coalfields was highlighted together with the future plans to relocate South African coal mining to the Waterberg coalfields in Limpopo Province. Finally, the future implication of mining legislation in South Africa was touched on.

The next chapter discusses the South African coal-mining industry in relation to the environment.

CHAPTER 3
COAL MINING AND THE ENVIRONMENT

3.1 INTRODUCTION

This chapter discusses the environmental issues and impacts with regard to the South African coal-mining supply chain. The types of environmental degradation (‘green’, ‘brown’ and ‘social’), emanating from coal mining activities are also discussed. The role of coal as a primary source of energy, which enhances development is elaborated upon under the general rubric of sustainable development.

The chapter also highlights international accords under the initiatives of the United Nations Framework Convention on Climate Change (UNFCCC) – the Kyoto Protocol of 1997 and the Copenhagen Accord of 2009. The King Report III on corporate governance, stipulating the importance of sustainability in companies/institutions incorporating economic, social and environmental issues in the corporate strategy, management forms, is revisited in this chapter.

The legislative environment governing the coal-mining industry and the environment are also discussed. The environmental impacts from coal mining and coal use, carbon credits and clean coal technologies are explored. Also included are the environmental impacts experienced by the leading coal mining industry supply-chain role players from the mines and logistics of transport to the customers. Finally, the future impact of coal mining on the environment is explained.

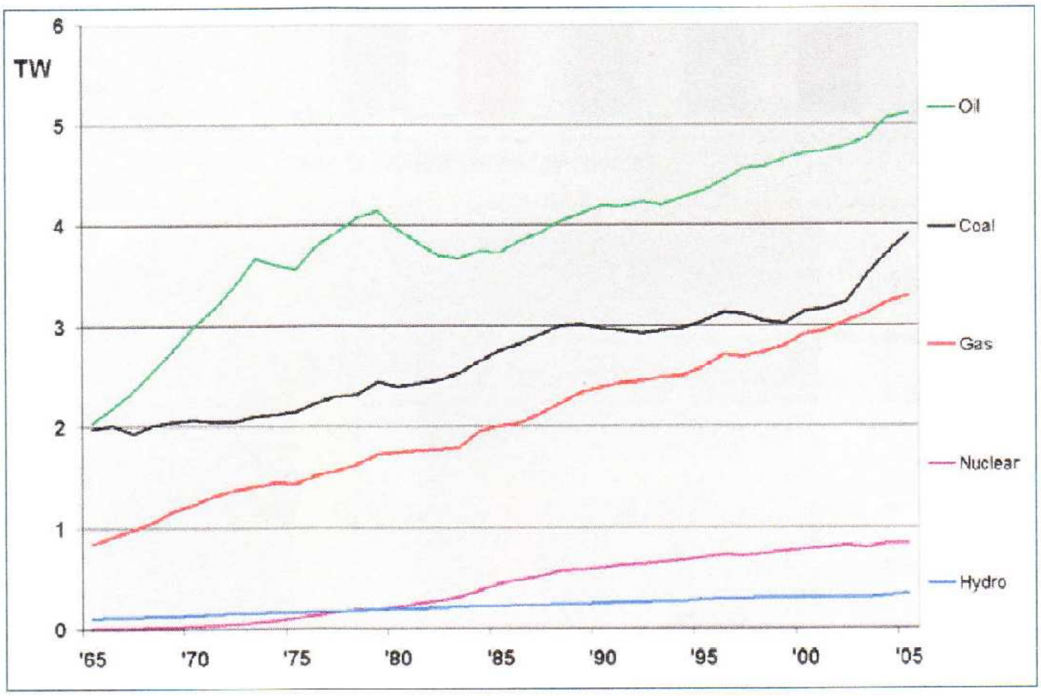
3.2 THE WORLD ENERGY CONSUMPTION AND THE ENVIRONMENT

According to (Kruger 2006:130), there are three types of primary energy: primordial, fossil and renewable.

- <u>Primordial</u>: these are the heat sources that originated with the formation of the earth. They include geothermal (hydrothermal and petro thermal)sources.
- <u>Fossil</u>: this is decayed organic (carbon-containing) matter, decayed and fossilised over millions of years that is extracted through mining processes.
- <u>Renewable</u>**:** this is the opposite of fossil and comprises naturally occurring energies 'not containing carbon' such as solar, hydro, wind, biomass, tidal, wave, geothermal and nuclear energy is also included in this category.

The global leading sources of energy are fossil fuels (oil, coal and gas) which provided between 80 and 90 percent of the total world energy in 2008. Between 2003 and 2008 coal, which is one of the dirtiest sources of energy was the fastest growing fossil fuel. The leading sources of energy are fossil fuels (oil, gas and coal), nuclear, and renewable sources (hydro, solar, biomass, wind, ocean current, geothermal and others) (Resource 2010:18). Graph 3-1 shows the world energy consumption by source.

Graph 3-1 World Energy Consumption, 2005



Source: Resource (2010:16)

Graph 3-1 shows the 2005 world energy consumption in million terra watts (TW) from the leading sources in order of volume:

- oil consumption about 5.3 million watts (TW);
- coal consumption about 3.9 million watts (TW);
- gas consumption about 3.4 million watts (TW);
- nuclear use about 0.8 million watts (TW); and
- hydro power consumption about 0.4 million watts (TW).

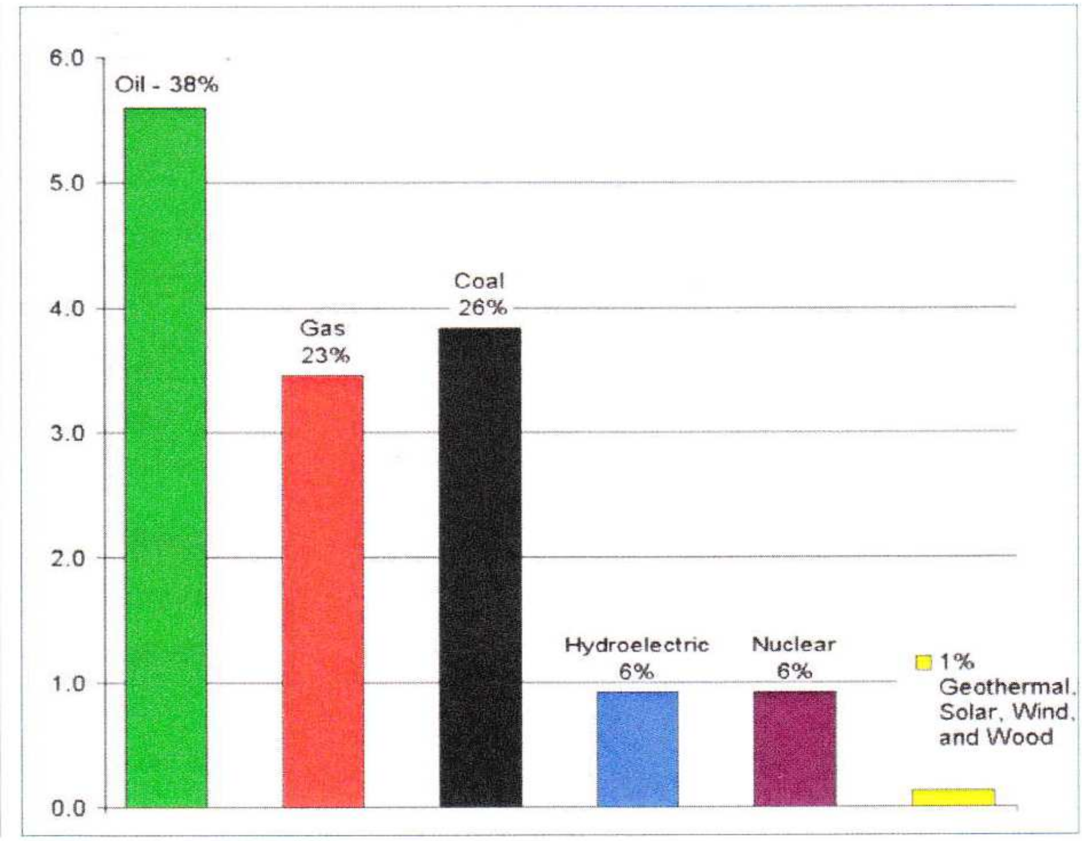
There is a direct/indirect relationship that exists between energy consumption and gross national product (GDP). It is possible to calculate the per capita energy consumption for all nations as the examples of some of the developed nations indicate. The US consumes about 25 percent of the total global energy, has a 22 percent share of the global GDP, a 5 percent share of world population and per capita energy consumption of 11.4 kilowatt per person (US Census Bureau 2009:1).

The most significant energy consumption growth in the world was recorded in China of 5.5 percent in the last 25 years and its population of 1.3 billion people consuming energy at the rate of 1.6 kilowatt per person (1.6kW/person). The energy per capita consumption in the developing countries is 0.7kW/person and Bangladesh has the lowest consumption with 0.2Kw/person (US Energy and Population 2008:1).

The global demand for energy is rapidly increasing with the increasing human population, urbanisation and modernisation. The growth in energy demand is expected to rise sharply in future (Abbott *et al.* 2009:28). Presently, the world relies heavily on fossil fuels to meet energy requirements. Fossil fuels (coal, oil and natural gas) provide about 88 percent of the global energy demands. The renewable energy and nuclear power contributes approximately 13.5 percent and 6.5 percent respectively. The fossil energy has adverse effects on the world's ecosystem and is blamed for contributing to the global climate change. SASOL's Secunda plant is one of the greatest emitter of carbon dioxide in the world (SASOL 2004:35).

Graph 3-2 shows the world energy sources and volume contribution.

Graph 3-2 Worldwide Energy Sources



Source: Resource (2010:18)

Graph 3-2 shows the global sources of energy and their respective contribution. Oil is the leading source of energy contributing 38 percent, followed by coal 26 percent, gas 23 percent, hydro electric 6 percent, nuclear 6 percent and other renewable energy sources such as geothermal, solar wind and wood that comprise (1 percent). Hence, the total global renewable energy sources of energy comprise 7 percent.

The environmental issues are part of broader developmental concerns which define and/or reflect relations to resources and power (McDonald 2002:57). According to Van Schalkwyk (2008:18) ‘since the 1960s there has been public concern over the “energy and environmental crisis” due to over-utilisation of energy by an affluent society resulting in severe degradation of the environment. The debate has been mainly to establish whether the energy and the environment are in conflict or whether actually there is a possible crisis. There has also been an ongoing global debate concerning the large emissions of atmospheric pollutants into metropolitan air basins from electric power generation plants and automobile exhaust fumes’. The impacts of climate change are outlined by Van Schalkwyk (2008:18) as:

- change in the global rain patterns;
- increase in various infectious diseases in Mexico, U.S., East Africa and Middle East;
- dwindling of water resources in many countries;
- frequent occurrence of violent storms in the tropical belt; and
- global food security being threatened by drought and bio-fuel production in search of cleaner, renewable energy sources pushing up food costs leading to riots in some countries.

In global perspective, the issue of climate degradation has become a concern due to changes in the atmosphere, which absorbs increasing volumes of carbon dioxide from the combustion of fossil fuels (Kruger 2006:87).

The global climate change results in global warming and flooding with catastrophic effects including the resurgence of diseases such as malaria and typhoid and starvation. The five leading global consumers of energy (China, India, Russia, United Kingdom and United States) constitute approximately 45 percent of the global population and they consume approximately 49 percent of the total energy consumed on earth. By 2003 the global oil consumption was about 71.1 million barrels per day. At that rate, it was estimated that the global oil will be depleted in approximately 50 years

(Asif & Muneer 2007:1388-1423). The latest British Petroleum (BP) Statistical Review of the World Energy in June 2010 indicated that the recoverable global oil reserves will be depleted in the next 45 years (MBendi 2010:1).

According to Asif & Muneer 2007:1388-1423), there is an intimate relationship between energy and environment as expressed in the following equation:

I = PAT

Where,

I = Environmental impact

P = The use of human population

A = Affluence of the population (such as per capita income and/or energy use)

T = Technology (such as energy efficiency, emission rate of air and water pollution.

The promulgation of the Mineral and Petroleum Resources Development Act, 2002 (Act 28 of 2002) has transformed the South African mining industry. The existing mining companies and the new entrants to the industry have to reapply for prospecting, exploration and production rights as the Act transferred all the mineral reserves to the State. In the coal-mining industry, the Act also opened up opportunities for smaller role players, comprising the Black Economic Empowerment coal mining companies. The promotion of new entrants to the mining industry and service provisions to the communities (housing, energy, water, healthcare, education and others) amounts to a call for sustainable development (Bloy 2005:35).

3.3 SUSTAINABLE DEVELOPMENT

Sustainable is defined as “supporting something that is true or maintaining something”. Development is defined as “a change from an original form, positively or negatively” Hence, sustainable development means maintaining a firm change in growth (Pipere 2006:7). According to the United Nations International Panel for Sustainable Resources, 140 billion tons of resources will be extracted from the earth's crust by 2050 to meet the needs of 9 billion people, assuming that the world will be run as it is presently. What is involved is the extraction of minerals and construction materials (Salgado 2010c:2). Sustainable development is determined by the balanced level of fluctuations of the country's economic growth. There ought to be a relative balance in the boom time (upswing) and contraction time (downswing) during the business cycle (Mohr, Fourie & Associates 2008: 511).

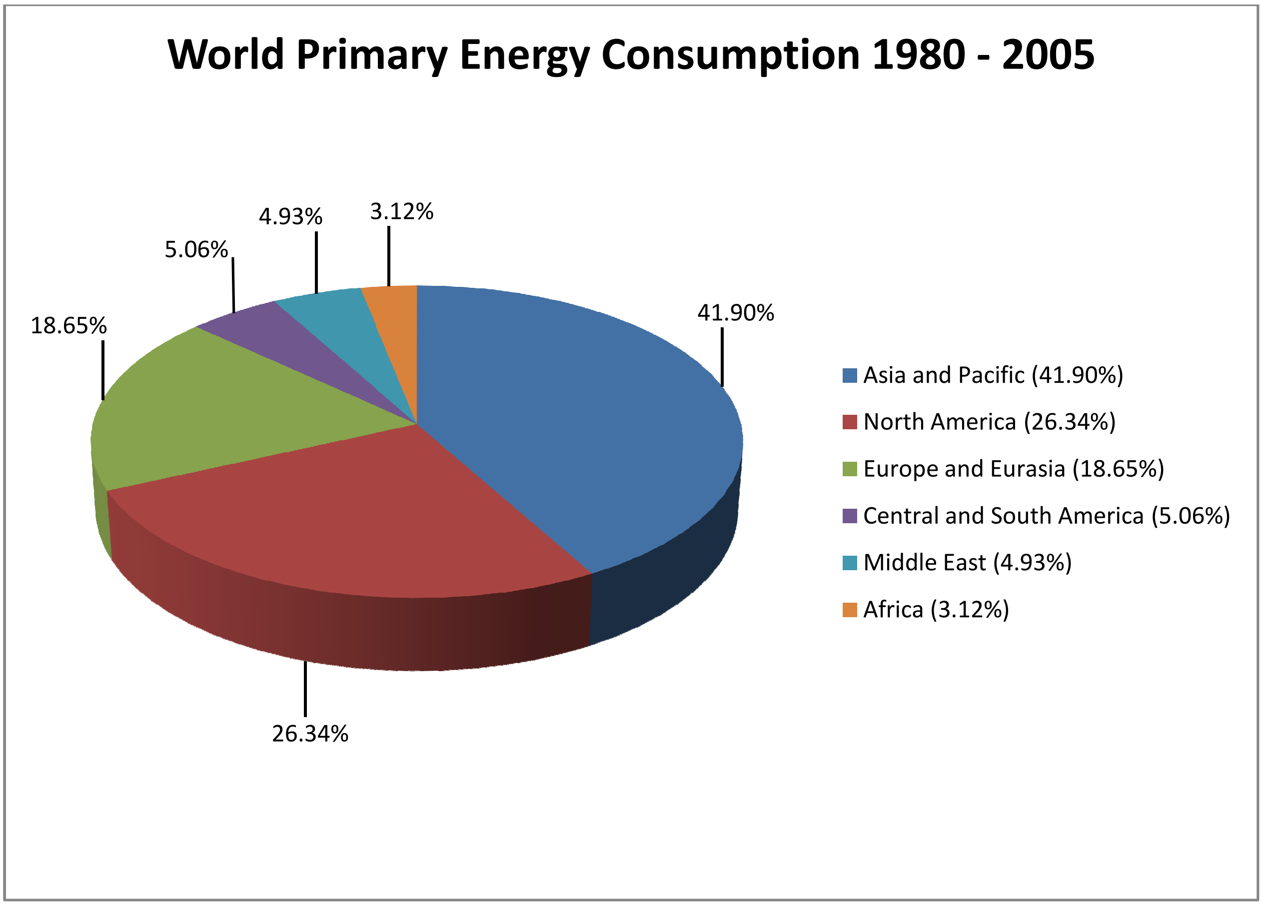
To realise sustainable development, the government, civil society and the private sector must collaborate in ensuring that mining, particularly coal mining, is not carried out in the water catchment areas, so that measures can be taken to treat acid mine- drainage and provision can be made for the proper rehabilitation of mines. The use of clean coal technology in future needs to be addressed as well. According to Van Weele (2003:25), environmental issues have become prevalent in the world today, mainly due to climate change, which is partly blamed on human factors that include manufacturing and in the use of fossil fuels which result in emission of greenhouse gases into the atmosphere. This is one of the factors which have led governments to issue strict regulations on environmental issues (Van Weele 2003:25).

'Coal mining is the second largest mining industry after gold, contributing approximately 2 percent to the South Africa's GDP. Its role as the leading source of primary energy in the country makes it a sensitive and important industry. The coal- mining impacts on the environment involve land, air and water resources. The mining processes contribute to water contamination, salination and siltation.' (McDonald 2002:159). The world has witnessed the debate as to whether or not energy use and the environment are in conflict and despite the debates, energy use is endemic to sustainable development (Kruger 2006:84-85).

Sustainability is a transformative paradigm which values, sustains and realises human potential in relation to the need to attain and ascertain social, economic and ecological wellbeing, recognising that they are deeply interdependent. Sustainable development involves the exploitation of natural resources, pollution, emissions and the deep concern of how to balance the idea of development, particularly that of economic growth and the endurance or sustainability of the environment (Pipere 2006:13). The other factor of sustainability is climate change. Most of the companies today consider climate change among the risk factors in determining their long-term strategies (King & Lessidrenska 2009:11).

The United States (U.S.) is the world's largest energy producer and consumer. In 2006 U.S. which has 5 percent of the world population produced 15 percent of the total global energy and consumed 22 percent of the total global energy. Graph 3-3 shows the rate of world primary energy consumption between1980-2005 in percentages.

Graph 3-3 World Primary Energy Consumption, 1980-2005 (%)



Source: (GARP 2009: 27)

Graph 3-3 shows the world's primary energy consumption by region for 25 years – 1980 to 2005. Asia and the Pacific were the leading consumers with consumption of approximately 42 percent followed by North America 26 percent. The Middle East was third with 19 percent, Central and South America fourth with 5 percent, Middle East fifth with 4.9 percent and Africa sixth with 3 percent.

3.3.1 THE KYOTO PROTOCOL

The Kyoto Protocol is a 1997 international treaty which came into use in 2005. The treaty emanated from the United Nations Framework Convention on Climate Change (UNFCCC) and binds most developed nations, except the United States, to a cap and trade system for major greenhouse gases. The treaty required the 36 industrial countries which signed it to reduce carbon emissions by an average of 5 percent from the 1990 levels by 2012. The developing countries were let off the hook. (Terblanche 2008:18). That means that the developing countries will not be affected by the carbon reduction quota for the stipulated period. Under the treaty, countries emitting less than their quota were to sell emission credits to nations which exceeded their quota. The treaty made it possible for developed countries to sponsor carbon projects that would provide a reduction in greenhouse gas emissions in other countries as a way of generating tradable carbon credits (Abbott *et al*. 2009:88).

According to Lennon (1997:46), the Kyoto Protocol treaty required the developing countries to focus on local and regional issues of climate impact and to determine how to anticipate, adapt to and where possible, to take advantage of such impacts. At the same time they needed to maximise their international cooperation in order to optimise their development while adhering to UNFCCC objectives without compromising their development. This cooperation was to include the transfer of clean coal technology (CCT) from the developed countries.

The Kyoto Protocol implementation debate on climate change intensified, leading to the preparation of the United Nations climate-change conference in Bali in December 2007 (Terblanche 2008:18). At that conference, some 11 000 science and governmental delegates from 187 countries resolved to launch a road map for negotiations that culminated in the International Conference on Climate Change in December 2009 in Copenhagen, Denmark (Van Schalkwyk 2008:17).

3.3.2 THE COPENHAGEN ACCORD

The Copenhagen conference aimed at reducing human carbon emissions. The United Nations Framework Convention on Climate Change (UNFCCC) Accord in Copenhagen, Denmark (UNFCCC 2009: 6-7) stated *inter alia* that:

- climate change is one of the greatest challenges of the present time and the global nations should aim to achieve the objective of the Convention by stabilising greenhouse gases at a level that would increase the global temperature below 2 degrees Celsius;
- while achieving the carbon reduction target, it is imperative that social and economic development and poverty-eradication are the priorities of developing countries. However, a low emission development strategy is indispensable to sustainable development;
- the developed countries should provide sufficient and sustainable financial resources, technology and capacity-building to support the implementation of adaptation actions in developing countries;
- delivery of reductions and financing by developed countries will be measured, reported on and verified as per the existing guidelines adopted by the conference and will ensure that the accounting process and finance is rigorous, robust and transparent;
- there will be incentives from the developed nations for efforts aimed at reduction of carbon emissions; and

- developing countries particularly those with low emitting economies should be given incentives to motivate them to continue to develop on low emission structures.

The Accord also came up with the “Global Environmental Facility” - funds set aside to assist the developing countries that will endeavour to reduce carbon emissions in their development. The Global Environmental Facility has enabled the developing countries to integrate climate change into their national development plans, to introduce policies to reduce and avoid greenhouse gas emissions and to increase those countries’ ownership of the situation. However, the Global Environmental Facility requires knowledge of management strategy to improve learning and to share best practices. The assessment of the implementation of this Accord will be completed by 2015 (UNFCCC 2009: 18-19).

The conference actually became deadlocked even though the Accord was signed by 28 nations, including South Africa. The conference deadlock was attributed to the lack of an acceptable target to reduce carbon emissions and omission of the Kyoto Protocol follow-up among other issues in the conference agenda. However, according to the South African chief negotiator at the conference, the reason for the conference deadlock was the hypocrisy of the developed countries. They offered to reduce carbon emissions by 19 percent below the 1990 levels by 2020. Developing countries viewed the offer as if the developed countries were trying to shift burdens, so they rejected the offer. (Harsch 2009:5).

3.3.2.1 Global Warming

Global warming is a phenomenon occurring with the gradual rise in the average temperature of the earth’s surface due to the increase of certain gases in the atmosphere (King & Lessidrenska 2009: 2). This process is described by Molteno (2008:191) as: “The earth receives radiation from the sun which passes through the atmosphere as short-wave light energy. After being absorbed by the earth’s surface, the radiation is then sent back to the atmosphere as long-wave heat energy which warms the air. The gases in the atmosphere like carbon dioxide, methane and water vapour absorb the long-wave heat and prevent it leaving the earth.

The greenhouse gases insulating the earth cause the ground and the air below to become hotter than before the formation of the insulating layer. This phenomenon is known as the “natural green effect” and all life on the earth depends on it. Without the natural greenhouse effect, the earth’s temperature would be too cold to sustain formation of any life. Therefore, the increase of greenhouse gas emission into the atmosphere increases the earth’s temperature as it holds more heat leading to enhanced greenhouse effect (global warming). In the last two decades, scientists realised that the current natural cycle of climate change was being accelerated by man-made greenhouse gas emissions or carbon dioxide released into the earth’s atmosphere by factories, cars, households and power stations among others. This triggered global multibillion-dollar research supported by world governments (van Schalkwyk 2008: 17).

3.3.3 King Report III

The 2009 King III Report applies to all entities regardless of manner and form of their incorporation or establishment. The report should be integrated across all areas of performance comprising the triple context of economic, social and environmental issues. The report should incorporate the future planning of the institution (PricewaterhouseCoopers 2010: 87).

According to King and Lessidrenska (2009: 15-16), today’s government and civil society organisations are required to report on their sustainability performance and impacts on their shareholders. A sustainable report contains economics, environmental and social issues referred to as the “triple bottom line” and governance information about the activities of the company. The report must contain both positive and negative elements of the three aspects of the company’s performance during the year under review. This reporting is based on the Global Reporting Initiative (GRI) also known as G3. The sustainability report should enable the stakeholders to be able to benchmark the company's performance against the performance of responsible corporate citizens. It should also provide stakeholders with the ability to evaluate how company performance is influenced by sustainable development by comparison with others in similar businesses.

According to PricewaterhouseCoopers (2010:92), the King Report III views governance, strategy and sustainability as inseparable factors. This is in line with the code's recommendations that good practice requires economic, social and environmental issues to be included in the corporate strategy, management, reporting and assurance throughout the year. The report requires institutions to have a sustainability strategy and policy. Sustainability must be part of continuous business activities. Sustainable development issues must be integrated into business management systems and institutions like risk, environmental, legal and financial aspects. Individual performance agreements should also have sustainability criteria built in. The institution should have qualified officials responsible for sustainable development and have one individual who should be the custodian of the content and assurance of the integrated reports.

The customers today are not "passive" but "active aggressive" consumers who are inspired by companies that have a good reputation through their social responsibility programmes. King and Lessidrenska (2009:180-181) stated that companies should maintain sustainable development even during the time of financial crisis in preparation for the future when the population increases. This is a way of building goodwill in order for the company to thrive through crisis. Part of sustainable development involves setting up a target for carbon emission in order to help improve our planet earth. The response to adapting to sustainable development is very encouraging in many countries including the United States, which has now agreed to set carbon emission targets.

3.4 THE LEGISLATIVE ENVIRONMENT

In pursuance of various government legislations, the South African mining companies ensure the relative sustainability of the operations, mitigation of impacts on the environment, as well as long-term sustainability for the immediate surrounding communities currently dependent on the mining activities (Bloy 2005: 38). Every mine has its own environmental management plan (EMP) based on the principle of integrated environmental management as laid down by the National Environmental Management Act, (Act No. 107 of 1998) NEMA. Auditing and monitoring of EMP form an integral part of the principles. The other requirements are the performance assessment and monitoring focus in compliance with the EMP and the appropriateness and effectiveness of EMP. The minerals Act requires integration of systems such as ISO 14 000. Mines applying for ISO 14 000 have greatly reduced reporting responsibilities in terms of the Act (Lloyd 2002:16).

The slow pace of transformation in the mining industry is partly blamed on the legislative environment. The Minerals and Petroleum Resources Development Act (MPRDA) Act of 2002 is said to be contradictory on such issues as tenure of mines and the lengthy licensing process. The Minister of Mineral Resources appears to concur with the claim and has imposed a six month moratorium on licensing effective 1 September 2010 – 28 February as the Act is being reviewed (Government Gazette 2010: 3).

The transformation process in the mining industry towards equitable ownership of the industry by people of all races, especially those who were previously disenfranchised, is far below the set target of 26 percent by 2014 as the 2009 achievement indicates about 8 percent. In recent months, the local press has carried news of the nationalisation of mines mainly due to the disparity in ownership (Khuzwayo 2010:1). Other issues include the rehabilitation of thousands of derelict coal mines and the spilling of acid mine drainage (AMD) which could trigger a national water pollution catastrophe (Salgado 2010a: 8). All these negative factors scare the industry, especially the prospective investors in coal mining. If the stalemate is not sorted out soon it could adversely affect the energy sector which is heavily dependent on coal. This would affect the national economy and sustainable development.

The South African mining industry, including coal mining, is guided by the *National Environmental Management Act*, (NEMA) 1998 (Act No. 107 of 1998) which is enforced by the Department of Environmental Affairs and Tourism. The Act states *inter alia* that:

- a description of the environment that may be affected by the proposed activity and the manner in which the geographical, physical, biological, social, economic and cultural aspects of the environment may be affected by the proposed activity should be provided;
- a description of the need and desirability of the proposed activity and any identified alternatives to the proposed activity that are feasible and reasonable, including the advantages and disadvantages that the proposed activity or alternatives will have on the environment and on the community, must be given; and
- a description and assessment of the significance of any environmental impacts, including cumulative impacts, that may occur as a result of undertaking of the activity or identified alternatives or as a result of any construction, erection or decommissioning associated with the undertaking of the activity must be declared.

The coal mining industry and all other organisations are required to adhere to these stated requirements and others contained in the Act. They are also required to submit a comprehensive environmental impact assessment (EIA) and environmental management plan (EMP) for all their activities that have impact on the environment (Government Gazette 2006:23).

This Act complements the Minerals and Petroleum Resources Development Act of 2002 (MPRDA) which regulates the mining industry and is enforced by The Department of Mineral Resources.

3.5 THE IMPACT OF COAL MINING ON THE ENVIRONMENT.

The environmental impact of the South African coal-mining industry supply-chain involves what the industry refers to as “green, brown and social” pollution. The ‘green’ denotes the effect on vegetation, ‘brown’ refers to dust from mining and industry and ‘social’ refers to the effect of noise from equipment, trucks and others on the community. The loss of biodiversity (plants, animals and land) that form the ecosystem, surface collapse due to continuous underground combustion in disused mines and soil destruction during the mining process are some of the green aspects of environmental degradation (Limpitlaw, Aken, Lodenijks & Viljoen 2005:2-3).

The mining process interferes with the above conditions on the surface and underground in the mining areas. According to Li, Zhou and Qin (2007:6), some of the environmental impacts of coal mining include:

Hydrological environmental factors**:** mining interferes with the drainage, storing and flow of water and this is more prevalent with underground mining.

Earth’s surface factors: mining cause movement, deformation, caving-in of the overburden strata and this situation affects the surface buildings, agricultural fields, irrigation infrastructures, bridges, railway infrastructure and electrical lines.

Coal gangue factor: This refers to the waste produced in the raw coal mining and washing processes. About 20 percent of coal gangue is produced during the mining process. The gangue emits toxic gases like carbon monoxide, sulphur dioxide and hydrogen sulphide that pollute the atmosphere.

Coal dust factor: The soot pollution from the coal production system, washing plants and coal dust produced during coal transportation pollutes the atmosphere.

Water pollution factor**:** This happens during coal mining and the coal washing processes. Coal mining and coal washing consumes a great amount of water that ends up as industrial liquid waste. Water pollution from coal mining is of four types – pollution to water from mine drainage, pollution to the environment, pollution to water from coal gangue and pollution to water from live waste water. All these water pollutants leave the water with tremendous volumes of suspended substances, heavy metals and other toxic matter which harms the plants, animals and humankind.

Air pollution factor**:** This results mainly from coal-bed methane gas, a greenhouse gas which is a serious security risk in coal mining due to its explosive nature. Other toxic gases like nitrogen oxide, sulphur dioxide and carbon dioxide also pollute the atmosphere. Air pollution is also produced by thermal processes used by mines which yield enormous amounts of smoke as well as the spontaneous combustion of stockpiles of discarded low grade coal. A major source of air pollution comes from abandoned coal mines in the Witbank area of Mpumalanga that have continued to burn for several years. Other sources of pollution emanate from the coal-fired power plants, dust from open pit and underground mines and the toxic chemicals used in the mining processes. All this pollution has a serious impact on the miners, surrounding communities and the ecosystem – the land and organisms living in it. (McDonald 2002:159).

The quality of mine water depends largely on the chemical properties and the geological materials that come into contact with it. Hence, the mining process disrupts the hydrological pathways and contaminates oozing water from aquifers (water absorbing rocks) depressing the water table. Such water is saline and has heavy concentrations of salts like calcium sulphate, sodium sulphate, magnesium sulphate or sodium bicarbonate, depending on the area. Water from Mpumalanga coalfields is rich in calcium sulphate while water from Waterberg coalfields has more concentration of sodium bicarbonate. This polluted water is also called ‘Acid Mine Drainage” (AMD). Research done in the last two decades indicates that neutralised AMD may be used for irrigation for some crops (Annandele, Beletse, Stirzaker, Bristow & Aken 2009: 337-338).

However, the environmental impact emanates from the effects of coal mining processes which include ground excavation, coal washing and stockpiling. The list also includes the environmental impacts of coal transportation, stockpiling at the customers' site and burning of coal at the customers' facilities (power plants, industries and homes). Other impacts includes the creation of gaping holes in the ground, soil removal and contamination, surface water and ground water contamination, creation of solid wastes in the form of discarded poor quality coal and air pollution. The other impacts include noise and ecosystem degradation (Lloyd 2002:1).

3.5.1 Soil

Mining activities cause severe disturbance to the soil environment in terms of soil quality and productivity and this is of serious concern worldwide (Mentis 2006:193). In terms of South African legislation, developers are required to rehabilitate ecological damage they inflict on the environment. In the case of the disused and discarded coal mines' rehabilitation has not appropriately been done in South Africa. Poor management practices and other negative impacts on soil ecosystems affect both physical and chemical properties of the soil. Disturbances of soil ecosystems affect the soil formation, energy transfers, nutrient cycling, plant re-establishment and long-term stability. Analysis of soil samples taken from seven sites indicated that the microbial ecosystems from the coal discard sites could become more stable and ecologically self-regulating, provided effective management to enhance carbon contents of the soil was maintained (Claassens 2003:3).

Returning the environment back to a similar, sustainable land use remains the greatest challenge for coal-mining operations. The impacts associated with coal mining include the formation of sinkholes, surface subsistence, destruction of geological and soil profiles, sponges, spontaneous combustion and others (Bloy 2005: 37).

Soil contamination by coal mine dumps was tested using the spinach plant (Spinacia Oleracea). Four levels of soil contamination were used in the test as (0 percent, 5 percent, 15 percent and 25 percent). The contaminated soils were analysed for acid/alkali level (pH), cation exchange capacity (CEC), soil organic matter (SOM) and concentration of selected metals. The plant grew under the first three categories of contamination with varying accumulation levels of selected heavy metals. However, no plant growth was recorded in the fourth category with the 25 percent contamination (Viren, Andrew & Sreekanth 2006:297-307).

Coal mining by underground and opencast methods has disturbed over 100 000 hectares of land in the Eastern Highveld grassland landscape. The South African mining companies endeavour to rehabilitate the land disturbed by the mining activities aiming to restore them to pre-mining agricultural land capacity (grassland). The rehabilitation process is described by Mentis as follows:

> ‘After opencast mining, the spoils that include the overburden are returned back into the pit. The top soil which is usually kept in a separate dump is then spread on top (landscaped) and re-vegetated. The pasture is rehabilitated with grass species that is planted with fertilizer to maintain a high production system for a few years. Subsequently, the native grass is planted without fertilizer as it was before mining, but a defoliation method is practiced until the grass can grow normally (defoliation is treating leaves with chemicals to sustain growth).’
>
> Mentis (2006:193)

3.5.2 Atmosphere

Coal is essentially a concentration of carbon atoms, originally harvested through photosynthesis from the atmospheric carbon dioxide by great ‘Glossopteris’ forests which became extinct millions of years ago. This carbon is being returned by humans to the atmosphere on a massive scale over a very short period of time. The global consensus is that greenhouse gases that include carbon dioxide emission contribute to the climate change (Prevec 2006: 4).

South Africa's high dependency on coal as a primary energy source and the energy-intensive mining and industrial sectors, means that South Africa has one of the highest levels of carbon dioxide emission per capita in the world at 1.5 percent and ranking sixth in the world with the U.S. in the leading position. No one is entirely sure where the pollution of the atmosphere will lead, although most acknowledge that it is ultimately bad news for the world's ecosystem (Prevec 2006:4). The South African coal mines drain methane gas through surface holes prior to mining. Methane gas is highly explosive and care in its handling is paramount. The coal mine methane (CMM) may be used in electric power generation, boiler fuel, transportation fuel and petrochemical feedstock. South Africa was ranked eleventh in the world in coal mine methane (CMM) emissions in 2000 (CMM Global Overview 2006:14).

According to Dharmappa, Wingrove, Sivakumar and Singh (1999:23), less than 20 percent of the water generated by the colliery is discharged off-site while the remaining 80 percent of the waste water is recycled back into the colliery. The collieries produce liquid, solid and gaseous effluents. The control of pollution results in water solution, which in turn result in soil pollution and finally all the pollutants end up joining the water body.

One of the projects of *Coaltech 2020* addresses the ash generated by coal-fired power plants which generate electricity. *Coaltech 2020* is a research programme formed by the major coal mining companies, various universities, CSIR, National Union of Mine Workers and the South African government collaborating to address the needs of the South African coal-mining industry. The ash project involves use of filtration systems to capture large and small ash particles. The ash is then collected and deposited in ash dumps. These dumps are rehabilitated when dumping has ceased (Bloy 2005: 37).

However, the collieries use water for drinking, in workshops, bathhouses, underground operations, washing, stockpile sprays, truck washing and road-dust suppression. The aquifer inflow water meets all the colliery water needs except for drinking water. Aquifers are the rocks in the coal mine that has water flowing through it. A New South Wales, Australia case study on waste management indicates that they sell for lawn treatment the slurry tailings effluent (waste product) from coal washing and processing, which transforms a waste product into a utility (Dharmappa *et al.*2000:26).

3.6 COAL BENEFICIATION

According to Singh and Beukes (2005:40), coal beneficiation is the process of the removal of the contaminants and the lower grade coal to achieve a product of quality which is suitable for the application of the user - either as an energy source or as a chemical agent or feedstock. When water is used, the process is called wet separation. In wet separation, approximately 200 litres of water are required for one ton of coal.

Research conducted by Coaltech on coal beneficiation established that the South African export quality coal can be beneficiated from coal discards and slurries (Singh & Beukes 2006: 40). Most coal is processed after leaving the mine to meet the demands of the quality market. However, in South Africa, the waste from processing (beneficiation) is used as power-station-quality coal. The ESKOM power stations burn almost incombustible coal wastes containing as much as 45 percent ash. Indeed, over 80Mtpa of coal is dumped, and some of the dumps have been smouldering for generations (Lloyd 2002: 3).

A process called ‘dry beneficiation is being developed to be used in arid areas where water is scarce. The impurities washed from coal are contained in the slurry water which collects to form dirty ponds or gets washed into nearby rivers and streams contaminating them. This is what happens with the Vaal River. The contaminated water also oozes into the ground and may contaminate the water table in areas where the water table is not very deep. Prinsloo (2009:2) provided some advantages and disadvantages for a dry coal beneficiation process:

Advantages**:** The process does not require an expensive dewatering process (such as pumping, screening, filtering and centrifuging).

Disadvantages**:**The dry processes produce higher ash content than coal cleaned in more efficient wet methods As for dust problems; dry processes have lower capacities than the wet methods.

The underlying factor for coal beneficiation is to reduce toxic materials which would increase environmental damage when coal is burned. Scientists have devised some processes under - Clean Coal Technologies (CCT) to limit excessive greenhouse gas emissions. Cleaning coal improves the energy content of coal. The future coal-fired power plants including the two under construction at Medupi and Kusile are modelled on clean coal technologies (ESKOM 2009:59).

3.7 IMPACTS FROM COAL USE

The environmental issues affecting the South African coal mining industry supply chain commences with the legislation requirements for the use of land, water and the surrounding areas around the mines, which also includes the communities, wildlife and natural habitat.

The other issues include solid waste and disposal sites, mine rehabilitation (soil and vegetation), air quality, surface and ground water pollution, among others. These are some of the environmental issues which the South African coal mining industry supply chain has to deal with in their operations. The National Environmental Management Act (NEMA) Act No.107 of 1998 stipulates that all companies must provide their environmental impact assessment (EIA) plans. The South African coal mining industry supply-chain environmental issues experienced by some of the leading role players in the industry are discussed later (Government Gazette 2006: 11).

Lloyd (2002: 3-4) highlights some of the impacts from coal usage as follows:

- emission into the atmosphere by coal-fired power plants annually: carbon dioxide (170mt), nitrogen (0.7mt) and sulphur dioxide (1.5mt);
- approximately 7 percent of electricity lost during transmission;
- ash from power plants used in cement making;
- burning coal at home for heating and cooking emits carbon monoxide and sulphur oxide into the atmosphere causing pollution.

More details on the impacts from coal are elaborated on under the industry role players.

3.7.1 Solid waste disposal

The mining industry is the largest contributor of solid waste in South Africa. For every ton of metal that leaves the mills, 100 tons of waste is created A major source of solid waste in the coal mining industry comes from the poor quality discarded coal and ash separated when coal is washed (beneficiation) and blended for quality (McDonald 2002: 158).

Extensive utilisation of coal ash is both technically and economically feasible if it is properly utilised and disposed of on the land. If the disposal sites are properly selected, constructed and managed, the waste materials can be properly processed for disposal. The risk then to ground or surface water supplies due to contamination by the trace metal constituents in the waste is minimal. Disposal of solid waste on land turns out to be an environmental problem which affects air quality, soil and vegetation, ground water, surface water and disposal site wash-out. The disposal of utility coal combustion by-products, whether in landfills or in ponds, can have significant effects on nearby surface water if sufficient precautions are not taken. A surface runoff from a disposal site or discharge of pond effluents will pollute nearby surface water (Jenkins & Hansen 1983:1- 5).

The phenomenon of land wastage by solid waste is supported by Vadapalli, Gitari, Ellendt, Petrik & Balfour (2008:1) who reaffirm that the bulk of fly ash is stored in ash dams and landfills that are an environmental hazard causing air and water pollution and degradation to the landscape.

3.7.2 Air quality

The issues of air quality are noted at the mines, where ventilation facilities provide clean air in the working environment. The power plants pose the greatest concern for air quality as they burn massive quantities of coal which emit massive greenhouse gases into the atmosphere. According to ESKOM (2009:80), the quality of air emission at ESKOM power plants has deteriorated since 2007 due to: power stations running at higher load factors to meet energy demand; poor quality coal; inadequate maintenance due to lower reserve margins; and poor performances in some power stations.

Both the mines and their customers that burn coal emitting carbon dioxide, sulphur and nitrogen oxides, adhere to local and international air-quality standards. ISO 14 000 provides a framework on managing environmental issues, which include air quality, water, waste disposal and vegetation (ESKOM 2009:87). The National Environment: Air Quality Act (39 of 2004) governs air quality and atmospheric emissions related to activities of power stations and other institutions emitting gases into the atmosphere (ESKOM 2009: 80). All coal mines contain methane, which is a greenhouse gas. The deeper the mine the higher the methane gas content found in the coal. As mining proceeds, methane is released into the atmosphere while some of the gas is trapped for industrial use (Lloyd 2002: 2).

3.7.3 Acid mine drainage (AMD)

Acid mine drainage (AMD) involves highly acidic water, usually containing a high concentration of metal sulphide and salt as a consequence of mining activity. The major sources of AMD include drainage from underground mineshafts, runoffs and discharge from open pits and mine waste-dumps, tailings and ore stockpiles, which make up nearly 88 percent of all waste produced in South Africa. Drainage from abandoned underground mine shafts into surface water systems either as decants or spillage may occur as the mine shaft fills with water (Manders, Godfrey & Hobbs 2009:1).

Rocks associated with coal deposits contain pyrite, an iron sulphide which mixes with oxygen in water to produce sulphuric acid. The sulphuric acid produces further reaction which produces iron oxide - a phenomenon called Acid Mine Drainage. The broken sandstones resulting from coal mining are pyrite-bearing rocks used to fill the pits. They allow water to flow through them easily, rapidly oxidising the pyrites and producing sulphuric acid. Oxygen produces a further reaction which forms iron sulphate and sulphuric acid in water. When this water emerges on the surface, further reaction occurs, producing more sulphuric acid and orange-red iron oxide (AMD) (Dharmappa, Wingrove, Sivakumar & Singh 2000: 26).

The acidic water in the pits also leaches out heavy metals such as manganese, copper, zinc, nickel, cobalt, cadmium and aluminium. This toxic seepage kills grassland, pans and wetlands, plants and creatures living in the area. A good example where AMD is a common occurrence is the Mpumalanga Lake Region (Abbott *et al.* 2008:28-29).

According to Bell, Bullock, Halbich & Lindsay (2001:203), old mine dumps (spoils heaps) have an abundance of coal due to poor coal separation processes used in the past. They were also poorly compacted, allowing the air through which supports spontaneous combustion. Consequently water permeates and forms acid mine drainage.

Acid mine drainage (AMD) is a serious problem in the South African mining industry. The Witwatersrand Basin is currently discharging polluted water at an annualised average rate of 15 million litres a day, which poses a severe environmental threat to water resources and the historically important Sterkfontein caves. A consortium of some mining companies has established a non-profit organisation – Western Basin Environmental Corporation (WBEC) to govern the water rehabilitation process, and investigate and develop sustainable initiatives in close consultation with the relevant authorities (Copans 2008:23).

Lang (2009:1-2) believes that the most effective remediation for AMD is the use of wetlands (natural or constructed) as they act as a filter and are able to remove many of the heavy metals by causing them to precipitate out of the water.

3.8 GREEN LOGISTICS

The green logistics entails covering only the planned kilometres to reduce the excess travelling, which reduces carbon dioxide emissions. A research conducted by the CSIR, Stellenbosch University and Imperial Logistics on South Africa's fast moving consumer goods (FMCG) industry distinguished the actual kilometres travelled (green) from the extra kilometres. The planned (actual) kilometres are the "green", while the difference (saved kilometres) – not covered because of good planning is "gold" – which denotes saving. The study established that South Africa has the highest per capita fuel consumption of 334 litres compared to the world average of 291 litres and Africa 64 litres. This is partly due to the country's uneven distribution of industry and population, where the concentration of the production sector and consumers is situated 600 kilometres from the coast (CSIR 2010: 45-46).

Green logistics is an environmentally responsible system which involves green status of the forward logistics process that is concerned with obtaining raw materials, processing, packaging and depositing of products and reverse logistics responsible for the disposal of wastes. Green logistics is based on a circular economy, which operates under the principle of reduce, reuse and recycle or the 3Rs. The three 3Rs are interpreted as reducing the resources output, reusing of the consumed products and recycling the waste (Li, Zhou & Qin 2007: 3-4).

Li Zhou and Qin (2007:4) define green logistics as "an environmentally responsible system that includes green status of forward logistics processes concerned with obtaining raw materials, producing, packing and depositing of products that also include reverse logistics of getting and disposing of the waste". According to (Li, Zhou & Qin 2007:8), green transportation of coal may be established by pursuing the following steps:

- utilising a transportation mode that emits less carbon;
- pursuing effective coal packaging in order to limit pollution and wastage on loading, unloading and distribution processes;
- establishing regional coal distribution centres where appropriate that will complete the distribution process instead of the traditional means of coal transportation direct to the customers/consumers. This way, coal pollution and wastage are reduced; and
- optimising the distribution route and enhancing a green management strategy.

3.8.1 Road transportation of coal to ESKOM plants

According to Bischoff (2009:100-101), coal haulage by road in South Africa intensified following the power crisis of the late 2007 and early 2008, which resulted from poor coal logistics that led to low coal stockpiles at the power stations. In order to meet the rising power demand, the medium-term solution to the crisis was to increase coal transportation by road to various power stations for example Camden, Majuba and Tutuka with trucks traversing various towns in the Southern regions of Mpumalanga, such as Amersfoort, Balfour, Bethal, Ermelo and Morgenson. A fleet of 5 100 trucks continue to traverse between the mines and the power stations daily.

The coal transportation to some of the Eskom's power plants causes great damage to the environment. For instance, every 30 seconds, a coal truck passes Ermelo town in the centre of Mpumalanga coalfields en route to deliver coal to Camden and Majuba coal-fired power plants. On a normal day Majuba power plant burns over 50 000 tons of coal and has the capacity to handle 1 300 trucks (Crotty 2008:3). ESKOM has made arrangements with the municipalities in the Southern regions of Mpumalanga for the road use and repairs to transport coal to the affected mines in the area in the medium-term, which costs the company R 535 million (ESKOM 2009:58).

The ESKOM's future plans for coal haulage by road include conducting environmental impact assessments on the routes, identifying the natural features such as rivers, streams wetlands and others requiring protection, continuing cooperation with the other role players including the municipalities and TRANSNET and continuing to assist in road rehabilitation in pursuit of meeting the country's energy demand (Bischoff 2009: 101).

3.8.2 Coal transportation to export terminal (rail)

TRANSNET's role in the coal industry supply chain is mainly transportation of export coal from Mpumalanga coalfields to Richards Bay Coal Terminal in Natal, a distance of approximately 650 kilometres. Presently, the terminal has a higher capacity than TRANSNET's delivery capacity, which represents a constraint in the industry. The terminal's coal-handling capacity reached 91mtpa in 2010, while that of TRANSNET is approximately 60Mtpa.

However, the coal depletion from Mpumalanga coalfields will bring changes as the mines relocate to Waterberg coalfields in Limpopo Province, a distance of over 1000 kilometres to Richards Bay. There are more environmental issues at Waterberg due to infrastructural shortages including those of water, rail and road. (Chamber of Mines 2009: 26).

The TRANSNET operations generate various types of waste which are separated, recycled or disposed of through carefully selected service providers. The company's environmental impacts include noise, dust, pollution and contamination, waste, traffic congestion, loss of animals or damage to property due to lack of control along rail lines or as a result of fire. The nature of environmental risks posed includes: exposure and spillage of asbestos fibres, which is rectified by rehabilitation and restoration of the contaminated sites, manganese pollution at Port Terminals and oil contamination of water and soil (TRANSNET 2009:103).

The company intends to install instruments for monitoring dust and air emission at strategic points identified throughout its operations. This measurement will form part of the carbon footprint study in the company. TRANSNET pursues its environmental affairs by strictly following laws and legislation on environmental matters, which includes conservation, waste management, air quality and occupational health and safety. The National Environmental Management Act No. 107 of 1998 is the main guide for environmental matters (TRANSNET 2009:103).

In order for South Africa to meet the future energy growth demands, more effort is required to develop the workforce and rail infrastructure. According to Prevost (2010: 17), TRANSNET was encouraged by India's prospective proposal to order 25 million tons of coal from South Africa commencing 2012, making the company belatedly launch its Quantum Leap Project, which includes increasing the rail capacity to 81Mtpa and also planning a Beyond the 81 Million Project. This is positive news for the industry and for prospective investors.

There was a 4 percent ton/kilometre increase on rail freight from 2007 to 2008 despite the economic hardship at the time. However, there was a rail freight decline during the period of 2007/2008 compared to the period 2004/2005 (CSIR 2009: 21).

This study has established that TRANSNET has constraints in infrastructure with an old and inadequate rail system, a shortage of locomotives, a paucity of skilled labour and operational issues. There are also huge disparities between rail and road freight with road freight taking the lion's share of 1404 million tons (83 percent) and rail 204 million tons IN 2008 (CSIR 2009: 20). These constraints have contributed towards the decline in export coal in the last five years, which can certainly be turned around by the model provided by this study in chapter 8.

3.9 IMPACT FROM ROLE PLAYERS

South Africa is one of the top 20 leading carbon emitters in the world. The country has received USD 500 million from the World Bank to assist in the alleviation of carbon emissions and for the promotion of energy-saving processes. Part of the programme is educating the energy users on energy-saving processes. These include: the use of fluorescent bulbs (long lasting and more efficient), use of solar heaters and power conservation by cutting unnecessary energy use at home and in industry (ESKOM 2009:49-50).

A comprehensive review of some of the leading members of South African coal supply chain was undertaken in order to ascertain the environmental factors in the value chain. The members reviewed include ESKOM (power utility company) as the leading consumer of the coal produced in South Africa, TRANSNET, the rail logistics' company and SASOL the leading synthetic fuels producer. The other companies are Richards Bay Coal Terminal (RBCT), the leading coal export terminal and Xstrata Coal, one of the five leading mining companies in the country.

3.9.1 ESKOM

In its pursuit of providing electricity to the country, ESKOM has policies which respond to climate and environmental issues. ESKOM has a six-point plan on climate change which was stated in ESKOM (2008:70) as: 'diversification, energy efficiency, adaptation, innovation, investment and progress'.

With electricity supply growing at approximately 4.4 percent per annum and limited changes to the traditional coal-fired technologies contributing to the electricity generation mix (approximately 88 percent), carbon dioxide emissions from electricity generation will be likely to more than double in the next 20 years. However, carbon emissions might decrease if clean coal technologies (CCT) are applied in future (Molteno 2008: 189). Some of ESKOM's future plans include:

- increasing the renewable energy component ;
- introducing an underground coal gasification pilot study that could improve efficiency;
- making use of pebble-bed modular reactor (PBMR) nuclear technology (research on-going); and
- collaborating with global organisations that address aspects such as emissions, trading, environmental policy directions and others.

The two new coal-fired power plants under construction- Medupi in Limpopo and Kusile in Mpumalanga are classified as supercritical plants which will employ new clean coal technologies (ESKOM 2008:71-73).

Particulate emissions

ESKOM controls particulate emissions from the coal-fired power stations by using sulphur trioxide fuel gas conditioning technologies which enhance the efficiency of electrostatic precipitators. The actual particulate emissions are done based on a 12-month moving index (12mmi). The particulate emissions for 2007 was 0.20 kg/MWh - that is a measurement in kilograms per Megawatt hour and 2008 it was0.21kg/MWh. ESKOM states that there was no reduction in 2008 due to the overall deterioration in power station plant performance, poor coal quality and the running of the power stations to their limits to avoid load shedding (ESKOM 2009: 81)

Gaseous emissions

ESKOM adheres to the guideline framework set out by DEAT in 2008 for emissions of sulphur dioxide and nitrogen oxide. The technologies applied include: low nitrogen oxide boilers; clean coal technologies; and flue gas de-nitrification (FGD). Calculation of nitrogen oxide, sulphur dioxide and carbon dioxide emitted from the power stations is based on coal characteristics and power station design parameters (ESKOM 2008:77).

Water usage

'ESKOM consumes approximately 2 percent of the fresh water resources in South Africa. Even though the country has a scarcity of fresh water, increased demand for electricity is expected to result in higher water consumption in future. It is estimated that water consumption for power generation is expected to increase by about 14 cubic metres per annum' (ESKOM 2008: 60).

Coal ash

'Some of the coal ash produced at the power stations is recycled. The recycled ash from some power stations (Lethabo, Matla, Kendal and Majuba) is used for cement production. The remaining ash is disposed of in ash dams and dumps next to the power stations and then rehabilitated to control fugitive dust. ESKOM coal-fired power plants produced about 34 million tons of ash in 2007 and 36 million tons in 2008' (ESKOM 2008:76- 80).

3.9.2 SASOL

SASOL's synthetic fuel plant in South Africa gasifies more than 26mtpa of bituminous coal. 'Using the Fischer-Tropsch synthesis process, synthesis gas is produced and used for the production of fuels and chemicals. SASOL l-Lurgi fixed bed dry bottom (FBDB) gasifyers are used for the conversion of coal to synthesis gas. This particular gasification technology is highly suited for the low grade coal utilised with the ash content as high as 35%, and the ash melting temperature as high as 1500 degrees Celsius. The gasifiers require lump coal with particle sizes ranging between 5mm and 100mm' (Keyser, Conradie, Coertzee & Van Dyk 2006: 1439).

SASOL (2008:82-85) highlights the following projects to address environmental concerns in their operations locally and internationally:

Moving towards cleaner production**: '**SASOL use the greater portion of its research and development (R&D) funds in support of the development of projects on GTL, CTL and the environment. At the Secunda and Sasolburg plants, the research focus is on saving water and managing effluent, reducing greenhouse gas emission, improving energy efficiencies, atmospheric chemistry and emission abatement, mining waste, recycling and ecosystem functioning. The company also collaborates with local and international universities' research groups and other institutions in R&D. It has cooperative arrangements with ESKOM in funding research into environmental issues of common interest'.

Targeting atmospheric pollutants: 'SASOL as a representative of Chemical and Allied Industries Association (CAIA) is assisting the government in standards development for emissions and ambient air quality as per the Air Quality Act of 2004. In South Africa, the Vaal Triangle and Mpumalanga Highveld regions where the majority of SASOL's operations are located have been identified as priority areas with respect to air pollution'.

Helping to reduce air pollution in companies**:** 'SASOL has working arrangements with Nova Institute in funding a project called 'Mama Basa' that teaches residents In the townships of Zamdela and Sasolburg safer methods of burning coal as fuel for cooking and space heating. They encourage domestic coal users to change from the conventional bottom-up method of igniting a coal fire to a more efficient top-down ignition method. The top-down method reduces the quantity of coal used as well as the particulate emissions and results in a more efficient fire with less smoke and reduced health risk'.

Working to minimise waste: 'SASOL strives to use better manufacturing processes in order to minimise both toxic and non-toxic wastes. In 2008 SASOL operations generated 96,000 tons of hazardous wastes representing a 30 percent decrease on the previous year. At the same time 980, 000 tons of non-hazardous waste was produced which was 2 percent lower than the 1,003,000 tons produced in 2007'.

Rehabilitating contaminated sites: 'SASOL has processes in place to rehabilitate land, soil and ground water which have been contaminated by their historical chemical and fuel manufacturing activities. In their South African operations, contaminated sites are found at Midlands sites in Sasolburg (mercury contamination) and at SASOL One site. In their United States operations dump sites are found at Lake Charles, Baltimore, Aberdeen, Jeffersontown, Oklahoma city and Mansfield'.

Cleaning up Mercury contamination**: '**The initial stage involves excavation and disposal of the contaminated soil at Holfontein hazardous wastes disposal facility in Gauteng. Alternative technology will then be used to treat the residual contamination left behind. The remedial process commenced in August 2006 and will be completed in January 2010'.

Managing land use and biodiversity: 'SASOL has established nature reserves on SASOL-owned land in South Africa which helps the company to conserve biodiversity and make these reserves accessible to the public for enjoyment'.

SASOL is the second largest polluter in the country producing about 14 percent of the carbon dioxide emission (De Wet & Van Heerden 2003: 474). The company aims to cut emissions by 15 percent in all operations by 2020 using 2005 as a baseline. It also aims to cut absolute emissions at new coal-to-liquid (CTL) plants commissioned before 2020 by 20 percent and those commissioned before 2030 by 30 percent (Salgado 2009b: 2).

SASOL's 'underground mining area covers 32 227 hectares (ha); surface mining area 1 284 ha; rehabilitated area 1 659 ha and the total land dedicated for conservation and biodiversity up to 2008 was 4 553 ha' (SASOL 2008: 82-85).

3.9.3 Richards Bay Coal Terminal (RBCT)

Richards Bay Coal terminal (RBCT) occupies a 260 hectare site at Richards Bay. It is the largest single coal export terminal in the world and is positioned in one of the world's deepest sea ports. Its operations are closely linked to TRANSNET's Business Unit National Ports Authority and Transnet Freight Rail.

'RBCT has a comprehensive environmental management system which minimises impact on the surrounding marine environment that supports animal, bird and plant life. It has the International Standardisation Organisation's (ISO) 14 001 accreditation since 2002. It subscribes to the three pillars of the triple bottom line, namely environmental, social and economic sustainability, and embraces these pillars to integrate its business practices. The company has developed strategies to measure and monitor impacts and to implement systems to ensure that the resources consumed are used in a sustainable manner and that negative impacts are reduced on a continuous basis' (RBCT 2008:1).

'RBCT is one of the signatories to the Energy Efficiency Accord signed on 17 August 2006 which commits the company to the National Energy Saving of 12-15 percent by 2015. This enables RBCT to benchmark its performance with its peers' (RBCT 2008: 1-2).

3.10 CLEAN COAL TECHNOLOGIES

The United Nations Framework Convention on Climate Change (UNFCCC) through the Kyoto Protocol of 1997 attributed climate change to a significant percentage of pollutants from fossil fuels combustion for power generation (Lennon 1997:45). The carbon emission to the atmosphere was also identified as a factor in climate change by the Copenhagen Accord in 2009 (UNFCCC 2009: 6-7). However, the critical issues are the importance of fossil fuels (oil, coal and gas) for energy generation for development, which cannot be substituted easily. Hence the global crusade for clean coal technologies.

In 1997 the South African electricity company ESKOM initiated an integrated electricity plan (IEP) to assess clean coal technologies (CCT) and made some choices like fluidised bed combustion plant (utilisation of discard coal), integrated gasification combined cycle (IGCC) plant, gas-cooled pebble bed modular reactors (PBMR), and continues to research for new technologies.

According to Lennon (1997: 47-48) the IEP process involves activities to:

- forecast energy and load shape;
- identify demand-side options;
- determine least cost combustions of the supply and demand options;
- evaluate risks and uncertainty;
- evaluate environmental impacts; and
- select and justify the preferred plan.

Clean production is a technology designed to prevent waste emission at the source of generation. The philosophy is “to produce better while polluting less”. This technology is also described by (Dharmappa *et al.* 1999: 23) as clean technology, waste minimisation, pollution prevention, waste recycling and resource utilisation.

The evidence of climate change provided by the “Inter-organisational panel of climate change” Resource (2010:16) indicates:

- rising sea levels and a melting ice cap;
- a sea level estimated to rise between 18-59cm in the coming century;

- ocean threats due to high temperatures, increased acidification, altered circulation and nutrient supplies; and
- the average ocean rise in the 20th century was 1.7mm per year, yet between 1993-2003 the rate was 2.5mm per year.

Energy production and consumption are huge contributing factors to the earth's atmospheric conditions.

According to *Resource* (2010:16), a peer-reviewed scientific study published by James Hansen and Pushker Kharecha in 2008 provided a baseline scenario on coal phase-out by reducing carbon dioxide emissions to the atmosphere to 0 percent level by 2050. The process entails:

- developed nations decreasing the carbon dioxide emissions from 2012 by 1 percent per year;
- a decade later (2022) developing countries halt increases in coal emissions;
- between 2025 and 2050 both developed and developing countries try to phase out carbon dioxide from usage; and
- by 2050 attain 0 percent carbon dioxide emissions.

The United States Department of Energy has commissioned Siemens to build its first carbon dioxide capture prototype project for coal-fired power plants in the United States. The pilot project will be built at Tampa Electric Big Bend plant to demonstrate 'post-cap' technology for post-combustion carbon dioxide gas capture. The technology involves treating a slipstream 1 megawatt (1MW) equivalent using amino acid salt formulation as a solvent for carbon dioxide absorption. Slipstream is the air sent out of a coal-fired power station exhaust system (flue gas). The amino acid is a non-toxic, biodegradable solvent which will result in a more environmentally friendly process (Abbott *et al*. 2009: 86).

The primary goal for this project is to reduce the large amount of energy traditionally needed to operate carbon capture technologies. The demonstration is expected to capture 90 percent of carbon dioxide from the slipstream of the flue gas from the power plant. The plant is scheduled to be operational by 2013 (*World Coal* 2010:1).

3.11 CARBON TRADING

Carbon trading reflects the environmental concerns of the global future outlook at the climate treaties initiated by the 'United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol of 1997' (Lennon 1997: 45) and the Copenhagen Accord of December, 2009. The convention, the Protocol and the Accord addressed the reduction of carbon emissions through a proposed carbon trading, among other measures. (UNFCC 2009: 6-7).

'The Kyoto Protocol treaty tied most developed nations to a cap (limit) and trade system for major greenhouse gases. Each participating country agreed to emission quotas with the intention to reduce overall emissions to the 1990 level by the end of 2012. The treaty made it possible for developing countries to sponsor carbon projects which would provide a reduction in greenhouse gas emissions in other countries as a way of generating tradable carbon credits. All members of the European Union ratified the Kyoto Protocol. The United States is the only industrialised nation which did not ratify the treaty and is not bound by i (Abbott *et al*. 2009:83).

The emission trading sets a limit or cap on the amount of emitted pollution by specific pollutants. According to Abbott *et al.* (2009: 86-87), government and international bodies issue emission permits to companies and organisations to allow them to emit pollutants into the atmosphere. The allowances those organisations are allowed to hold are called 'emission credits'. However, companies wishing to increase emissions must buy credits from those that emit fewer pollutants. The transfer of allowances is referred to as a trade. Indeed, the buyer is paying a charge for polluting, while the seller is being rewarded for having reduced emission by more than what was needed. This reduces pollution at the lowest cost to society.

3.12 ENVIRONMENTAL FUTURE IMPACTS

The latest estimate is that the world coal reserves will last another 150 years at the present consumption rate. Thus, the world will continue to depend on coal for energy for many years to come. Hence, there is a need to investigate more innovative ways of coal utilisation which will reduce adverse effects on the environment. It is estimated that the world population will grow by 25 percent in the next 25 years requiring a considerable increase in energy demand. This calls for increased investment in nuclear power and renewable energy (solar, hydro, biomass, ocean current, wind and others) (Lok 2009: 22).

It is estimated that in the next decade South Africa will increase coal production by 75 million tons. There is also a prediction that at some point in the future coal production will stagnate and will not be able to meet the country’s energy demand, which will require energy import from other countries, increased use of renewable energy and nuclear power. It is also estimated that the nuclear fuel will last the world another 80 years. All these factors require strategic energy planning for the medium and long-term (Smuts 2008: 33-37).

South Africa’s future environmental concerns in the coal supply chain will be dictated by the Department of Energy’s integrated resource planning (IRP2) to be released in 2010 and the impacts of the last United Nations climate conference in Copenhagen, Denmark in December 2009.

According to Salgado (2010b:19), ‘South Africa has plans to reduce carbon emissions 34 percent from a business-as-usual scenario in 2020 and 42 percent in 2025. The plans include: establishing 100 megawatts of concentrated sola power; establishing 200 megawatts of wind power; a roll-out of solar water heaters; and achieving energy efficiency savings of up to 15 percent by 2015'.

Fauconnier (2005:5-8) provides some insight on the medium-term and long-term solutions on the prevailing coal mining and rising energy demand, as stated below:

Medium-term**:** According to official calculations of 'South African coal reserves in 1987, almost half of the country's *in situ* reserves (reserves existing naturally) were in the Waterberg basin with only 27 percent in the Witbank and Highveld coalfields. It is believed that by 2020 many of the coal mines in the Mpumalanga coalfields will have closed down or be near exhaustion, hence, the relocating of the new power stations to Waterberg basin will be paramount. The resources sustainability issues in Mpumalanga coalfields highlights the issue of the environmental sustainability of a region'.

A European satellite image above Mpumalanga and Gauteng indicate a high level of nitrogen dioxide atmospheric pollution due to coal-based electricity generation in the region. The phenomenon is called Lloyd's Blanket Atmospheric Pollution, which is enough reason for relocating the coal-fired power stations in future (Abbott *et al.* 2009: 87).

Long-term**:** 'From South Africa's perspectives, the Inga Project in the Democratic Republic of Congo is the project with the greatest potential for electricity generation in the longer term (15-20 years). Its potential capacity could sustain electricity supply to the Southern African countries and other parts of Africa for a long time. Hence, to bridge the gap between energy resources provided by the Witbank-Highveld coalfields, Waterberg coal is the solution. There are enormous coal reserves at Waterberg for development of the additional power generation capacity with the least threat to the environment compared to the Witbank-Highveld area. Besides, mining expansion to the Mpumalanga area will be more economical due to the availability of low cost coal, shared infrastructure and shorter lead-time compared to the stand-alone options such as the Inga Project' (Fauconnier 2005: 7-8).

Prevost (2010:17**)** believes that in order for South Africa to meet the future energy demands much more effort will be required in developing the workforce (engineers, production personnel and managers) to create new capital expansion programmes, and to operate and maintain resulting projects. Expanding coal export capacity would require an infrastructure upgrade. RBCT attained 91mtpa handling capacity in 2010 and, as has already been mentioned, TRANSNET has belatedly launched its Quantum Leap Project that includes increasing rail capacity to 81mtpa.

The future energy generation and consumption from coal sources will require technologies which control carbon emissions and sustainable modes of transport on land (rail and road) (*Resource* 2010:16).

Carbon emissions**:** more than three-quarters of South African carbon emissions come from energy generation and consumption. Hence, it is apparent that energy mix to reduce the coal source drastically is a prerequisite in order to realise the anticipated target for 2020 and 2025. ‘The current coal-fired power plants will be decommissioned by 2025 when their economic life expires. However, the new coal-fired power plants that will come on stream in future, including the two new ones, constructed at Medupi and Kusile, will use clean coal technology (CCT)’ (ESKOM 2009: 59).

Initial plans which entailed decommissioning the old coal-fired power plants in 2025, would be replaced by 14 nuclear power plants and smaller units of renewable sources (solar and wind) (Salgado 2009a: 2).

3.13 CONCLUSION

The effects of coal mining on the environment were discussed. The roles of energy in development and the environmental impacts thereof in sustainable development were explored The United Nations Framework Convention on Climate Change (UNFCCC), which has led the world focus on integrated development due to climate change was discussed. The strategies adopted on carbon emissions are contained in two main Accords: Kyoto Protocol of 1997 and the Copenhagen Accord of 2009. The role of integrated development was covered under the King Report III of 2009 that reiterates the importance of all types of companies/institutions focusing on the triple bottom lines, namely economic, social and environment in their corporate strategy, management and reporting throughout the year.

The legislation governing the coal mining industry and the environment were described, indicating their impact on the industry. The impacts on the environment from coal mining, coal use and from the leading role players in the coal mining industry were articulated. South Africa’s two leading consumers of coal and polluters through carbon emissions ESKOM and SASOL were commented on.

The issues of clean coal technologies, carbon trading and anticipated future environmental impacts were also covered.

The next chapter discusses supply-chain and logistics management with the emphasis on supply-chain management in the South African coal-mining industry supply chain.

CHAPTER 4
SUPPLY-CHAIN AND LOGISTICS MANAGEMENT

4.1 INTRODUCTION

This chapter discusses supply-chain and logistics management functions in business. A model of a supply chain is provided to explain its roles and importance in business operations. Various types of supply chain, their design, planning and risks are also discussed. .

The role of logistics in the supply chain is highlighted in a discussion of various transportation modes (rail, road, conveyor and marine) used in the South African coal mining supply chain.

4.2 SUPPLY CHAINS AND SUPPLY-CHAIN MANAGEMENT

The Council of Supply-Chain Management Professionals describes supply-chain management as follows:

> "Supply chain management encompasses the planning and management of all activities involved in sourcing and procurement, conversion and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners which can be suppliers, intermediaries, third party service providers and customers. In essence, supply chain management integrates supply and demand management within and across companies".
>
> (CSCMP: 2000-2010:1)

A supply chain is the integrated network for the physical flow of goods from suppliers through transformation to the distribution of finished products. A supply chain can be in two parts: 'Materials management' or the flow of materials from suppliers through to the finished product and 'physical distribution management' or the distribution of the finished product to the client (Waller 1999:535).

Leenders *et al.* (2006:6) define supply chain management as;

> "the design and management of seamless, value-added processes across organisational boundaries to meet the real needs of the end customer. The development and integration of people and technological resources are critical to successful supply chain integration".
>
> (Leenders *et al.* 2006:6)

Further, Fayazbakhsh, Sepehri and Razzazi (2009:27) define supply chain as:

> "a collection of suppliers, manufacturers, distributors and retailers along with all interrelationships. It includes several businesses which are related to each other directly or indirectly to satisfy customer demand and have several stages and may provide different types of products."
>
> (Fayazbakhsh, Sepehri and Razzazi, 2009:27)

The supply-chain management (SCM) entails an integrative philosophy of managing the total flow of a distribution channel from suppliers to the ultimate user. A typical supply chain in fast moving consumer goods (FMCG) comprises suppliers of raw materials, manufacturers, retailers and consumers (Van Weele 2003:209). The ultimate objective of a supply chain is ensuring customer satisfaction, improving quality, reducing cost and improving services (Govil & Proth 2002:67-68). International studies indicate that supply-chain cost to the business ranges between 15-20 percent (Taljaard 2005:17).

Usually, there is a dominant player or partner in a supply chain. This is the partner who is closest to the consumer, not in terms of physical proximity, but in terms of hearing the customers' voice and responding to it, which can either be the raw material supplier, manufacturer, the transporter, the wholesaler or the retailer (Govil & Proth 2002:8).

4.2.1 A typical supply-chain model

A typical supply chain commences with planning and proceeds with the processes of sourcing, procurement, conversion (manufacturing), transportation (logistics), coordination and collaboration with suppliers and customers (CSCMP 2000-2010:1).

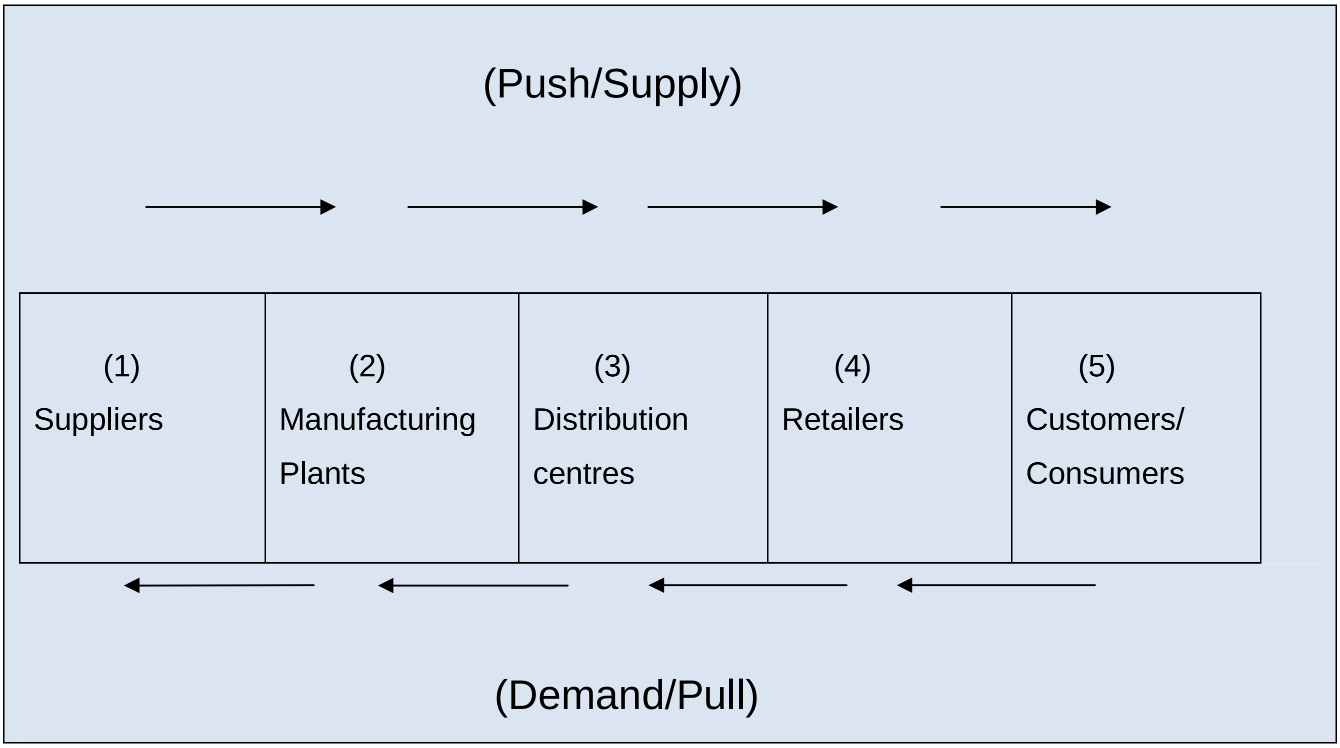
According to (Sadler 2007: 1), a basic supply chain comprises:

- a focal company which forms goods or services for a set of consumers;
- a range of suppliers of raw materials and components;
- distributors who deliver goods to customers; and
- modes of transport which move products between each location in the chain.

According to Swaminathan, Smith and Sadeh (1998:607), 'a typical supply chain comprises a network of autonomous or semi-autonomous business entities collectively responsible for procurement, manufacturing and distribution activities associated with one or more product lines.' The establishment of a Supply chain prompts a risk-benefit analysis of operations (supply chain reengineering) in order to improve performances such as on-time delivery, quality assurance and cost reduction. A supply chain is about sharing information then acting on it (Wise & Fagan 2001: 60).

The supply-chain management (SCM) integrates supply and demand management within and across companies and has configurations which are "communicative, collaborative and coordinated" (Stock 2009:148). According to Taljaard (2005:17), 'in order for a supply chain to function optimally, integration of the system is a prerequisite. This entails that each element of the supply chain is individually developed to its full potential prior to its alignment with the whole supply chain system. This provides it with a competitive edge over the competitors leading the (SCM) to achieve desirable outcomes like reduction of total cost of supply-chain activities, reduced lead-times, and valued-added services of logistics and reduction of capital investment.' (Taljaard, 2005:17), A typical supply-chain model comprising raw materials suppliers, manufacturers, distribution centres, customers and end-users/consumers is provided, demonstrating a generic manufacturing facility and downstream flow to the end-users/consumers.

Figure 4-1 A Typical Supply Chain Model



Source: Own model

The process of the supply chain model demonstrated above commences with a manufacturing facility's plans to manufacture products for sale to the end-users through the retail outlets. The raw materials/components are ordered from suppliers and brought to the factory warehouse in preparation for manufacturing. The manufactured products are stored in the finished goods warehouse before being moved to the distribution centres (DCs) where the customers and retailers orders are dispatched. Customers in turn buy the products from retailers. This is the consumption stage where the defective products bought may be returned to the retailers for replacement or cash back. The retailer then returns the damaged goods to the manufacturers for reprocessing or disposal (reverse logistics).

The arrows pointing to the right denote the ‘push’ supply chain, where the demand of the product/service emanates from top (manufacturing) downstream to the customers/consumers.

The arrows to the left denote the ‘pull’ supply chain, where the demand originates from the downstream (customers/consumers) to the manufacturers and suppliers upstream.

Well-established companies strive to treat their suppliers as customers so as to maintain good relations which enhance operational efficiency (functional, relational, service and brand reputation). These are the valued chain links for the supplier-customer relationship (Walters 2009:1).

4.2.2 Supply-chain design and planning

Supply-chain planning involves all planning activities necessary to operate effectively across the supply chain. These include all functions required to develop the product, buying materials required to develop the product, buying materials required to manufacture it, making the product and shipping it to its customers. These functions need comprehensive planning to quickly and flexibly react to the increasingly complex demands from the customers.

Modern innovations in technology have added credible planning tools which include Enterprise Resource Planning (ERP), Materials Requirement Planning (MRP), Supply Chain Planning (SCP), Order Management System (OMS), Warehouse Management System (WMS), Manufacturing Execution System (MES) and Transport Management System (TMS), among others. The key areas of planning are in marketing, production, distribution, materials and finance (Gattorna 2003:311). Supply-chain system planning and coordination includes materials-planning processes both within the enterprise and between supply-chain partners. The specific components are sales and operations management, capacity constraints, logistics requirements, manufacturing requirements and procurement requirements (Bowersox, Closs & Cooper 2007:118).

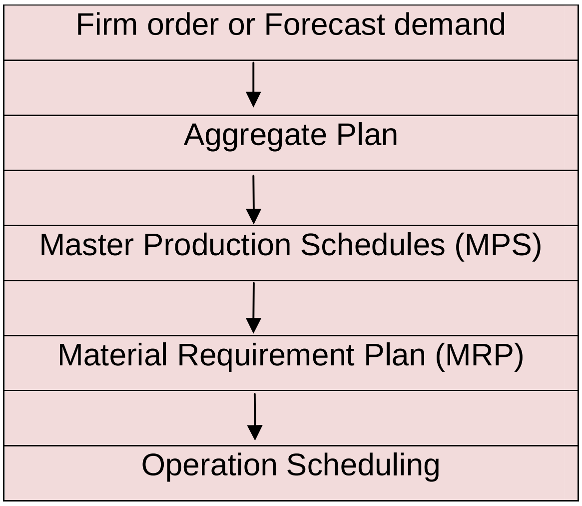
In distribution, there is time-phased planning which is mainly used by retail outlets that receive products frequently. Time-phased planning allows only the scheduled deliveries to avoid product and traffic congestion at the warehouse. In sales-forecasting, capacity planning is used for predicting future constraints based on sales forecasts, estimated inventory and replenishment requirements as calculated by a time-phased planning system. The time-phased planning and future constraints with capacity plans enable users to identify future constraints in enough time to pursue alternatives (Martin 2001:63-66).

Designing a supply-chain system commence with a comprehensive plan for future estimated requirements for the end products. The estimate is derived from input from marketing and, where applicable, firm orders from clients, anticipated orders and ’promised’ but not yet booked orders. When these estimates are established, all the end products are put together as demand for the production. Eventually, ‘the total demand is translated into capacity requirements, the aggregate demand into resource requirement of material quantities and labour/machine hours using appropriate standards to establish production capacity.’ (Waller 2003:331).

Designing the supply-chain network of companies is preceded by specifying the basic business objectives. These involve developing, producing and delivering a product or service or both to customers/end-users for financial reward or profit. Supply-chain design may also be referred to as the process of setting up the supply-chain infrastructure and logistics elements, which include determining the location and the plant capacity, distribution centres and transportation modes, among others (Sharifi, Ismail & Reid 2006:1081-1083). It is relatively easy for a company which produces just one product to convert aggregate demand into production units, but this becomes more complex for companies that produce a diverse range of products (Waller 1999:331).

Figure 4-2 depicts the planning stages in an operation:

Figure 4-2 Planning Stages In the Operation (Computerised)



Source: (Waller 1999:331)

There are five planning stages in an operation. The process is computerised as indicated in the above figure. It commences by compiling the firm orders received and forecast demand or both. The orders and the projections (forecasts) are tallied. The aggregate plans form the basis for MPS. Then the MRP is finalised and the operation scheduling certified to commence production.

Supply-chain management entails collaboration of firms for the purpose of improving operational efficiency and productivity. The process involves functional connectivity and collaboration from materials suppliers, through production and distribution to the customers (Bowersox, Closs & Cooper 2007: 5).

4.3 TYPES OF SUPPLY CHAINS

According to Sadler (2007:228), there are three strategic factors which are used to determine the types of supply chain: the product's life cycle from introduction to decline; product processes (journey) to the final stage; and the type of supply chain involved (efficient, lean or quick in response).

4.3.1 Pull versus push supply chains

Usually, there are two types of supply chains: 'pull' systems and 'push' systems.

The Pull system: A pull system is when the outlet at the lowest level or end of the distribution network, usually the retailer, initiates the order. This is an innovative marketing strategy in which retailers 'pull' the product through the distribution or supply chain network.

The challenge to the supply chain is to find ways in which the demand penetration point can be pushed as far upstream as possible. 'Through sharing information on real demand it is possible that supply chain partners are able to align themselves with the needs of the market. Synchronised with the moving of the demand penetration upstream, should be the movement of the 'decoupling point' as far as possible downstream. The decoupling point is the point of commitment – the moment where inventory is committed to particular customers or markets. The decoupling point represents the transition from forecast-driven activities to demand-driven activities' (Christopher & Peck 2004: 85).

According to Christopher and Peck (2004:104), a demand-driven supply chain is driven by three key issues:

- coping with volatile demand: moving the demand-penetration point further upstream and utilising mass-customisation strategies;

- creating agile supply chains: inventory based on real demand; and
- connecting the supply chain through shared information: supply-chain partners collaboration to enhance performance.

It is a demand-led customer response supply chain which enables the customer-service representative to access sales, marketing and supply-chain information in the ordering process, which offers the customer alternatives. Integrating demand and supply chain creates a dynamic model of a value-chain network (Walters 2009: 5).

The Push system: In the ‘push’ system, the supplier at the beginning of the network, usually the manufacturer produces the finished products according to the manfacurer’s own master production schedule (MPS). This MPS is usually established according to estimates of clients’ demands and then modified to suit the company’s resources available at the manufacturing site. Material is ‘pushed’ through the distribution channel when the products are ready (Waller 2003:505-507). In a push system of planning and control, material is moved on to the next stage soon after it has been processed. This is done with central instructions, such as MRP. (Pycraft *et al.* 2005: 363).

The push supply-chain design for manufacturing and material flow decisions are based on forecasts. The wholesaler uses the retailer’s order to forecast customer demand. The upstream supply-chain partners who have no access to customer demand patterns are forced to carry more in their inventory and increase their production costs due to their poor logistics management. A typical push mechanism relies on MRP (Hugo, Badenhorst-Weiss & van Bilton 2004: 76).

The coal-mining industry supply chain is a “pull” supply chain system as the customers/clients place their coal orders with the coal mine and the mining company organises delivery with the transport-logistics company. The inspection of coal at the mine’s stockpile is conducted by the power station’s representative to ensure that the right quality is delivered as the bulky nature of coal loads would be cumbersome for returns. The power stations’ coal orders are based on the power plants’ requirements as stipulated in the supply contract. The export coal, industry and merchants' coal orders also follow the pattern where demand precedes the order (pull system).

4.3.2 Customer-focused and process-centred supply chains

The concept of customer-focus in a supply chain entails the focus by the members of the supply chain (value chain) on customer satisfaction. The 'client is king' concept means that the customer is very important for the business (Waller 1999: 758). Pycraft *et al*. (2005: 476) believe that in a customer-focus supply chain the supplier's understanding of the customer's needs is enhanced, thereby creating more cohesion and understanding within the supply chain. Usually, satisfied customers are delighted. The satisfaction emanates from timely delivery of goods or services. The supply chain provides these services at a lower cost than their competitors and at the same time they demonstrate their social and environmental consciousness (Anklesaria 2008:32).

The Customer-centric approach brings with it effective decisions which culminate in improved marketing and financial performance in the value chain. Value-chain management is about the understanding of value based on customer perception. Customer value includes benefits in functional, relational and service aspects and brand reputation (quality). Leading organisations (world class) think and treat their suppliers and the suppliers' suppliers as customers in order to harmonise the customer-supplier relationship. "Value in the business market is the worth in monetary terms of technical, economic, service and social benefits a customer company receives in exchange for the price it pays for a market offering" (Walters 2009: 105).

Value is realised when goods or products arrive where they are needed (destination) (Modares & Sepehri 2009: 13). Customer value may be represented in an equation as provided by (Walters 2009: 105) as follows:

> VALUE= Results produced (Value-in-use) for customer less price for the customer + Process quality + cost of acquiring the product.

The process-centric concept in a supply chain involves effective use of EDI or the internet connectivity to ensure information flow for the smooth running of the supply chain. The process involves organisational design, process re-engineering, change and performance management (West & Lafferty 2007: 101). A comprehensive process description of the supply chain focuses on the functional cycles (customer order cycle, replenishment cycle, manufacturing cycle and procurement cycle) and requires the infrastructure to support the processes involved. The cyclical view is important as it facilitates the setting up the processes, or the setting up an information system to support the supply-chain operations (Chopra & Meindl 2004:9). ‘A supply chain provides all the customer requirements, which include the total flow of materials and information. The customer is the only one who possesses “real” currency in the supply chain. Hence, the customers’ decision to purchase trigger action along the whole chain’ (Pycraft *et al.* 2005: 475).

Process-centred supply chains align and synchronise assets against customer needs, optimise the assets, supply customers efficiently, deliver on the customer promise and create value for the customer. ‘Customer-focused supply chains are customer- driven, collaborative among the functional organisations, increase alignment and synchronisation of the supply chain and ultimately improve the shareholders and customer’s value’ (West & Lafferty 2007: 101-104).

4.3.3 Functional and innovative supply chains

Functional products include the common goods which people buy on a regular basis, for example groceries from retail stores and petrol from petrol stations (consumer goods). Such products satisfy basic needs and have a stable, predictable demand and a long life cycle which attracts competition and often leads to low profit margins. Innovative products are rare and new products which have unpredictable demands but attract higher profit than the functional products have a shorter life cycle, usually a few months (Fisher 2000:130).

The two products require different types of supply chains. Fisher (2000: 130-132) described the two types as:

> “a supply chain for functional products (that) entails converting raw materials into parts, components and eventually finished goods then transporting them from one point in the supply chain up to the consumer. Market mediation ensures that the variety of products reaching the marketplace matches what consumers want to buy. The other one being the innovative supply chains which enhance the market. High profit margins and the importance of early sales in establishing market share for new products increases the cost of shortages and the short product life cycles increase the risk of obsolescence and the cost of excess supplies. Process and technology change periodically. In some instances, the changes are faster as in the information technology. Hence, it is paramount for both production and communication to keep abreast with changes (innovation) occurring in business at all times” (Fisher [2000] *In* Pycraft *et al.* 2005: 263)**.**

Most companies in the supply chain keep their pricing systems as deep secrets. However, the leading company in the supply chain is required to approach issues with the other members of the value chain in a diplomatic manner in order to obtain general pricing data as the detailed cost data are not necessary at the beginning. The chain members must show a willingness to share relevant information and work towards a common goal of reducing both supplier and customer costs (Anlesaria 2008:33). Supply-chain responsiveness entails a supply-chain’s ability to respond to wide ranges of quantity demanded, to meet short lead time, to handle a large variety of products, to meet high service level and to handle the supply uncertainty. The more functions the supply chain is able to meet, the more responsive it is (Chopra & Meindl 2005: 35).

4.3.4 Future supply chains

The three features of a successful future supply chain are described by Jain and Benyouncef (2007: 469-496) as:

- strategies, technologies, people and systems;
- environmental protection as the global ecosystem will always be strained by growing population and the emergence of new high- technology economies; and
- re-engineering (customisation, lean, agile, flexible, demand-chain management and integrated supply-chain scheduling issues for long supply chains)

(Jain and Benyouncef, 2007: 469-496)

4.4 AN INTEGRATED SUPPLY CHAIN AND COLLABORATION

An integrated supply chain involves the delivery of raw materials from the suppliers to the warehouse of the production centre. These materials are moved for production and the finished products are stored in another warehouse. The finished products are then delivered to a distribution centre using selected transportation modes. The products are then moved downstream to the retailers or customers (Waller 1999: 496).

The integrated supply chain requires that the movement of materials and products and the provision of service throughout the firms in the chain are planned and managed in a systematic way using electronic and person-to-person communication. Systems use reduces the costs of purchasing, production, transport, inventory and distribution. Close coordination between these operations improves customer service and reduces the total cost incurred. Hence, an integrated supply chain caters for one group of products within a supply network (Sadler 2007:247).

According to Taljaard (2005), the internal integration of a supply chain requires advanced information technology (IT) tools and skills to implement it. External integration usually led by the major players in the supply chain focuses on the optimal flow from raw material to consumer by focusing on the coordination of the supply chain activities. Hence, managing an integrated supply chain entails improvement of the stock price, income statement and balance sheet, cash flow and optimisation of enterprise resource planning (ERP) at the clients' businesses. The benefits accrued include cost reduction and service improvements, improvement on return on investments and assets, reduced information technology expenses through minimised customisation and improved profitability (Taljaard 2005:17-18) .

The collaborative supply chain is where independent but related firms share knowledge and skills to meet their customers' needs. Such collaboration creates competitive advantage (Zacharia, Nix & Lusch 2009: 101). The purpose of supply chain collaboration is to deal with constraints in order to bring the supply-chain performance to a high level. The Theory of Constraints' five-steps approach are applied in production to cater for the systems approach (Kampstra, Ashayer & Gattorna 2006: 317).

Collaboration is the means by which companies within the supply chain work together towards mutual objectives through sharing of ideas, information, knowledge, risks and rewards. The success of collaboration depends very much on technology and the members of the supply chain may have their own systems or outsource from outside. The benefits accrued are across the board from raw material suppliers to the customers. It brings down inventory, increases forecast accuracy and increases revenue to the customers. The material suppliers' benefit from reduced inventory, lower warehousing costs, reduced stock outs and lower materials acquisition costs. The suppliers, on the other hand, experience faster and more reliable deliveries, lower capital costs and lower freight costs. These are some of the collaboration benefits for the value chain role players (Cohen & Roussel 2005:140).

Collaboration enables parties in the supply chain to combine knowledge and capability better than acting in isolation. Sridharan and Simatupang (2009: 255) state the following three characteristics of collaborative practice:

- Decision synchronization: joint initiatives of cooperation in decision making, planning and operational context for identifying key decision points, distributing responsibilities, reconciling conflicting goals, sharing resources, handling differences and sharing problems;
- Information sharing: optimisation of communication at all levels;
- Incentive alignment: the degree to which chain members share costs, risks and benefits.

(Sridharan and Simatupang, 2009: 255)

Fayazbakhsh, Sepehri & Rezzazi (2009:28) agree with the mechanism of coordination that a bilateral relationship between a buyer and a seller is a contract. Decision making based on shared information by members of the supply chain is the second major type of coordination mechanism. This form of coordination is facilitated through customer relationship management (CRM), supplier relationship management (SRM), e-market places, trading agents and sharing business information.

According to Furter (2005:13) collaboration in the supply chain improves responsiveness and flexibility in operations and that it integrates costs and production factors which result in improved customer service, lowered manufacturing costs, reduced inbound and outbound transportation costs, improved information flow and reduced inventory. According to Walters (2009:8), collaboration seeks to implement customer-based solutions using shared resources and producing shared benefits which involve: co-creativity, co-productivity, co-competition, co-density and complementors.

Co-creativity**:** the involvement of consumers and distributors in the design and development of product services.
Co-productivity**:** increased role of suppliers, distributors and customers in the supply chain.
Co-competitors**:** situations where competitors share mutual facilities.
Co-density**:** the extent to which members of the value chain share commitment.

Complementors**:** market segments which offer opportunities to increase the existing markets, for instance financial institutions which fund customers to buy homes, cars, furniture and so on.

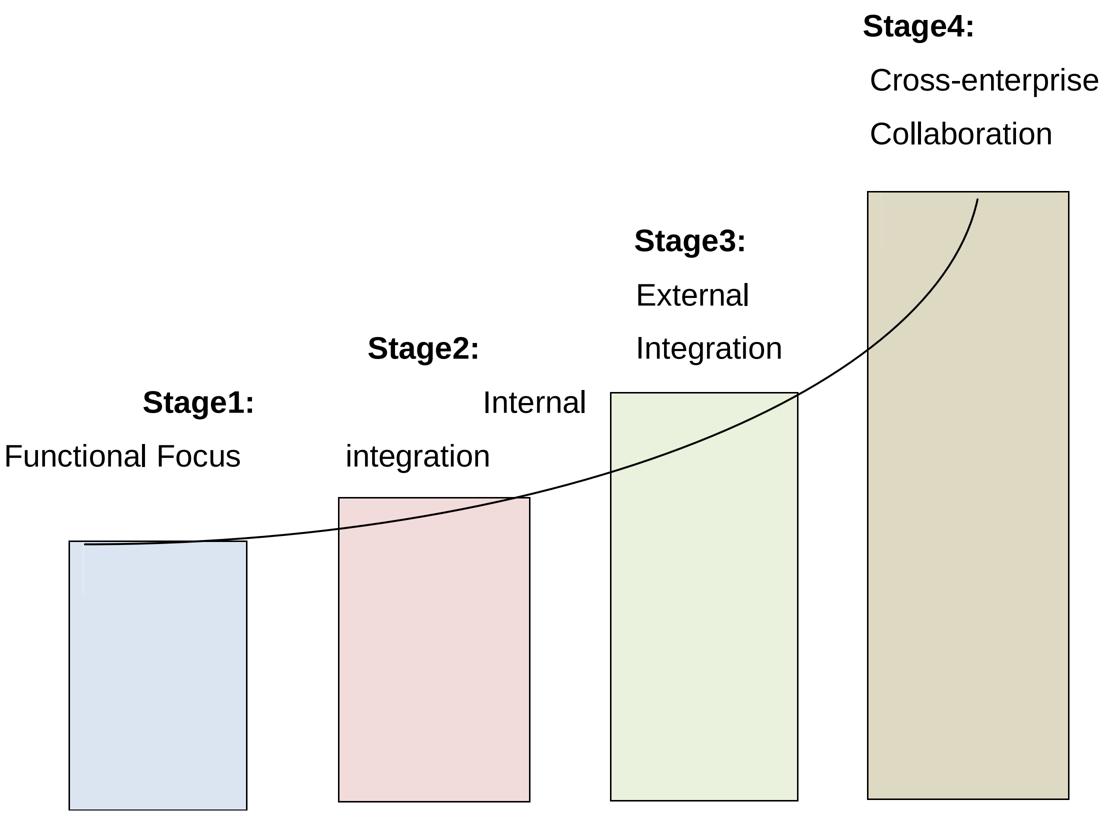
The supply-chain configurations are communicative, collaborative, coordinated and competitive (situations where competitors share mutual facilities). Excellent supply-chain strategies and operations result from good collaboration, coordination and integration. However, the key challenges to successful global coordination of the supply chain are non-stationary (there is continuous flow of goods), variability and inventory balances (Stock 2009:153-157).

Effective collaboration is a source of competitive advantage which aims to improve customer service, profit generation, asset utilisation and cost reduction. The goal of collaboration should be realised within each entity (cross-functional) and between chain entities (cross-enterprise). According to Kampstra *et al.* (2006:322), supply chain collaboration (SCC) has three loops: the strategy loop; the change loop; and the control loop.

> "The strategy loop**:** choosing strategic partners, identifying supply chain strategy and aligning with corporate strategy.
> The change loop: determining which entity should change and what should change.
> The control loop: governing the transformational change, governing strategic objectives and allocating benefits and burdens."
>
> (Sridharan and Simatupang, 2009: 255)

The SCC should be an on-going process and there should be the desire to collaborate from all parties. Figure 4-3 shows the different phases of supply-chain maturity growth.

Figure 4-3 Four phases of Supply Chain Maturity Growth
(Levels of Integration and Collaboration)



Source: Super Group, 2005:11

<u>*Stage 1: Functional* focus</u>

During this phase the entity focuses on the internal functions by department with emphasis on MRP (Material Resource Planning) and Material Requirement Planning (MRP II).

<u>Stage 2: Internal integration</u>

At this stage the organisation sees the value of inter-departmental cooperation and complete internal integration is accomplished by consolidating the weaker areas in the operations in order to enhance output.

Stage 3: External integration

External integration is realised as the entity shares management and operations issues with the other members of the value chain, suppliers, distribution centres and logistic companies providing transportation. Cooperation is established through areas such as purchasing, transportation, marketing, product promotion, communication (use of information systems, for example EDI and ERP) and other functions which increase profitability and value to the customer.

The coal supply chain becomes constrained during this phase as the level of collaboration is not cohesive enough in the rail freight, which is fully government owned through TRANSNET and the customers (mines are privately owned). The collaboration with the other major customer ESKOM is also lacking due to policy issues as both are state-owned corporations with different operating mandates. This constraint is to be addressed by the coal supply-chain model in chapter 8.

Stage 4: Cross-enterprise collaboration

Cross-enterprise collaboration happens when all the members of the value chain and the role players have achieved complete integration. Communication is enhanced through electronic data interchange or other advanced information systems for example ERP. During this phase orders or any other supply-chain problems are easily traceable at any point in the value chain.

However, this phase does not exist in the South African coal supply chain as it is inhibited by the unbalanced ownership of the value chain (CSIR 2009: 16). The producers of coal (mining companies) have no role to play in the freight movement, which inhibits communication both on the government side and on the side of the private sector. This is one of the constraints facing the South African coal-mining industry supply chain. However, the constraints' alleviation model provided by this study in chapter 8 hopes to correct this situation.

4.5 SUPPLY-CHAIN RISKS

Like any other business operations supply chains carry risks. In this regard, Waters (2007:79-99) provides three categories of supply-chain risks: internal risks, supply chain risks, and external risks.

'Internal risks: consists of operations and occurrences such as accidents, the reliability of equipment, loss of the IT system, financial and delivery schedules; management decisions such as size of a production batch, safety stock levels, financial and delivery schedules; and the regulatory aspects of activities covered by regulations such as delays in issuing licenses, lack of clarity in requirements, fiscal and taxation policies.

External risks: these are external to the organisations in the value chain. They include risks from suppliers such as reliability, material availability, lead-times, delivery, industrial actions and so on and risks from customers such as variable demands, payments, order processing, customised requirements and so on. These risks are mainly caused by inadequate cooperation between chain members.

External risks (environmental)**:** they are external to the supply chain and arise from interactions with its environment. Examples include accidents, extreme weather, legislation, pressure groups, crime, natural disasters war and so on.

According to Waters (2007b:79) the rate of risks from the main role players in the supply chain include: supply chain disruptions (34 percent); suppliers (15 percent); customers (13 percent); nature and government (4 percent); and various combinations of parties (6 percent)'.

Traditional risk management has been one-dimensional focusing on loss, but with the advent of the supply chain the focus is broadened by increased processes and greater outreach (crossing regional and international boundaries). Taking an example of South African companies, business uncertainty and risks emanate from exchange rate fluctuations, distant export markets, high fuel prices, infrastructure limitations (road and rail), public transport inefficiencies, complex supply chains and pressure to enhance performance. The complexity in the supply chain involves processes of sourcing, manufacturing, distribution and extension across boundaries (regional and international). Internationally, the impacts of war and terrorism add more uncertainty and risks to business.

According to Riaan and Walters (2009:14-15), these uncertainties may be controlled by supply chains striving to incorporate in their culture the means of dealing with perceived risks and having a supply-chain professional managing the channel processes. The long-term solution of dealing with uncertainty would be the introduction of an integrated supply-chain risk management (ISCRM) programme at tertiary institutions to develop undergraduates and postgraduates who would steer risk management leadership in an industry.

According to Shah (2009:150-153), supply-chain risks can be classified into three main categories: supply-chain disruptions; supply-cost uncertainty; and demand uncertainty.

<u>Supply-chain disruptions</u> involve managing events which have low probability of occurrence but have high impact on the supply chain. Disruptions include delays, loss of opportunity for making a sale and security concern like the terrorist attack on the U.S. in September 11, 2001 (9/11).

<u>Supply-cost uncertainty</u> is concerned with price changes and currency exchange rate fluctuations. For instance, the price of crude oil moved from 40 United States Dollars (USD) to 147 USD a barrel in about two years. As firms tried to adjust to the price of USD 200, the price shrunk back to 40 USD in just six months.

In <u>demand uncertainty,</u> products are classified into functional products and innovative products. In the case of functional products, the focus is on meeting predictable costs effectively, while for innovative products the focus is on meeting unpredictable demand-cost effectively.

The coal supply chain is vulnerable to all these kinds of risks; and the model to alleviate the established constraints in chapter 8 also highlights these risks.

4.6 COAL-MINE SUPPLY CHAIN

This study has established that the coal-mining supply chain is a “pull” supply-chain system as the coal orders from the customers precede the supply fulfilment by the mine. The main customers are the power stations, which are usually supplied on long-term supply contracts. The other coal orders are also based on imports and industry demands. In the coal supply chain, raw materials are natural resources and products are energy products. According to Jiang, Zhou and Meng (2007:2-3), the coal industry depends on independent coal resources exploration, exploitation, coal marketing, transportation and coal users.

Exploration → Exploitation → Marketing → Transportation → Consumption

‘Resources exploration: involves establishing the viable mining location, available quantity and quality of coal, economic and national conditions of exploitation.

Coal exploitation**:** the process of production which includes coal mining and transportation. Hence, coal production systems include coal mining, storage, handling, preparations, transportation and other aspects. Coal production can influence quality depending on the type of mining (opencast or underground mining). Opencast mining is not complicated since coal is available near the surface. Underground mining systems consist of upgrading the transport system, the ventilation system, drainage system and quality detection systems.

Coal marketing**:** involves the establishing of coal marketing channels and the formation of a marketing network. Through the marketing chain, coal is transferred from enterprises to the end users. The main task of coal marketing is to conduct analysis that meets the demands of targeted users. The role of the sales department is to provide information feedback regarding the users' needs.

Coal transportation**:** involves the use of various modes of transportation from the coal mine to stockpile yards at the mine and at the customers (end-user's) premises. . The transportation modes include conveyor belts, railways, road transport, barges or ships and inter-modal transport (where more than one mode of transportation is used).

Coal consumption: the coal consumers play a key role in the value realisation of the product. About 90 percent of coal users comprise electric power utilities, metallurgical and chemical industries. It is the users' demand which warrants the establishment of mining companies'.

The main participants in coal enterprises are the coal enterprise itself, transportation/logistics companies and resource exploration and exploitation. Most of these companies are monopolistic in their operations so it is paramount for the coal industry to build relations with them and to maintain these at the highest level in order to enhance operation.

4.7 THE SOUTH AFRICAN COAL-SUPPLY CHAIN

The South African coal mine supply-chain model involves three aspects : the mine; stockpiling/processing; and transportation. The mining process involves the removal of top soil and overburden that are dumped for later use in the mine rehabilitation after the closure of the mine. The coal mined is mixed with stones and stockpiled as the stone removal process takes place. The stones removed are dumped using earthmoving equipment and trucks (Wilhelm 2009: 7).

The sorted out coal is stockpiled and ready for distribution to the power stations via conveyor belts, road and rail. Most of the old power stations in the Mpumalanga coalfields were built next to a coal mine so that conveyor belts could be used. With the depletion of coal from the Mpumalanga coalfields, extra coal has now to be sourced from other mines to top up the power stations' capacity, and the deliveries are done mainly by road except for the Majuba and Tutuka power stations where rail is also used. The export coal is taken through the beneficiation process first since it is of higher quality than the coal burned at ESKOM's power stations. It is predominantly produced from the Mpumalanga coalfields and is transported by rail to the export coal terminal at Richards Bay, a distance of approximately 650 kilometres. At the terminal, coal is stored in stockpiles for various exporters from where it is loaded onto ships. The metallurgical coal and coal for other industries and merchants are also beneficiated and transported via rail and road.

Figure 4-4 A South African Coal Supply Chain Model

Mine	Stockpile (coal and overburden)	Transportation Mode	Destination
		Conveyor belt	Power station Sasol
		Rail	Export (RBCT) Industry Traders
		Road	Power station Dump site

Source: own model

The coal used to produce synthetic fuels by SASOL is mined from the SASOL mines and transported to the conversion plant via conveyor belt and road. The company uses rail to transport export coal to the Richards Bay Coal Terminal (RBCT).

Figure 4-4 shows a model of the South African coal mining industry supply chain indicating the three stages of the supply chain:

Stage 1: Mine

Mining processes which include the removal of the top soil and overburdens and dumping them.

Stage 2: Stockpile/beneficiation

Sorting out stones from coal and stockpiling it ready for delivery to the power stations and some beneficiated for delivery to other destinations (export, metallurgy and other industries).

Stage 3: Transportation (to customers/export terminal)

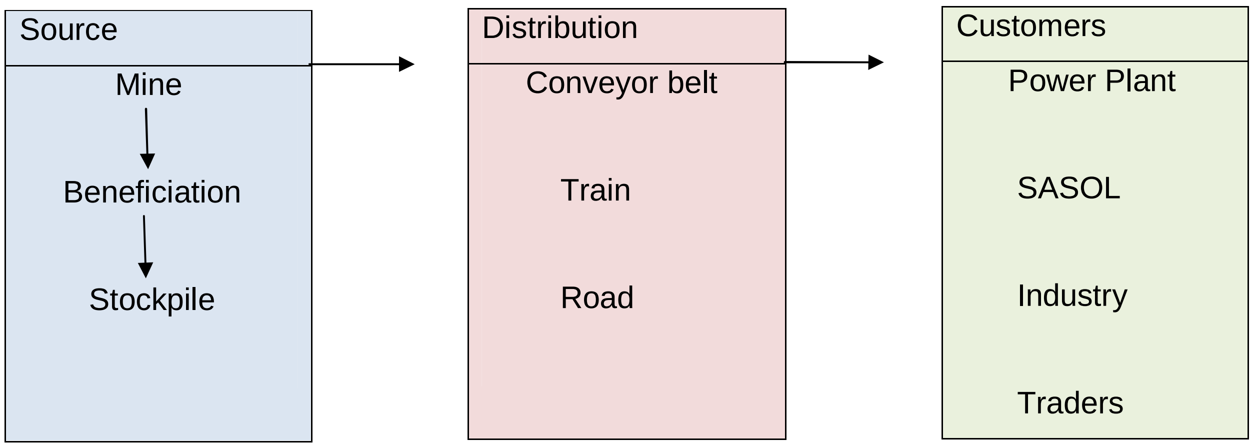
Transportation to customers: power stations, export, SASOL, metallurgy and other industries. Transportation modes used include conveyor belt, rail and road. The power stations receive 70 percent of the coal supply via conveyor belt and 30 percent of the rest is sent by road and rail. The export coal is transported to the export terminal by rail which loads it onto the ships for transportation to the overseas customers.

It is apparent that the South African coal supply chain revolves around the mining companies with their marketing and trading companies together with other independent coal-trading companies; the logistics company Transnet; the leading consumers Eskom coal-fired power plants; petrochemical industries; metallurgical; domestic and export market. There are coal stockpiles next to mines, at the points of consumption and at the export terminals at Richards Bay Coal Terminal (RBCT), Durban Coal Terminal (DCT) and Matola Coal Terminal (MCT), Maputo, Mozambique. RBCT is the leading coal terminal in South Africa with a present capacity of 72 Mt/a and will be upgraded to 91 Mt/a by 2010, DCT has capacity of 2.5 Mt/a and MCT has capacity of 4 Mt/a, (DME 2009: 5).

The South African coal mining supply chain falls into two categories: domestic and export coal supply chains.

Figure 4-5 shows the South African domestic coal supply chain:

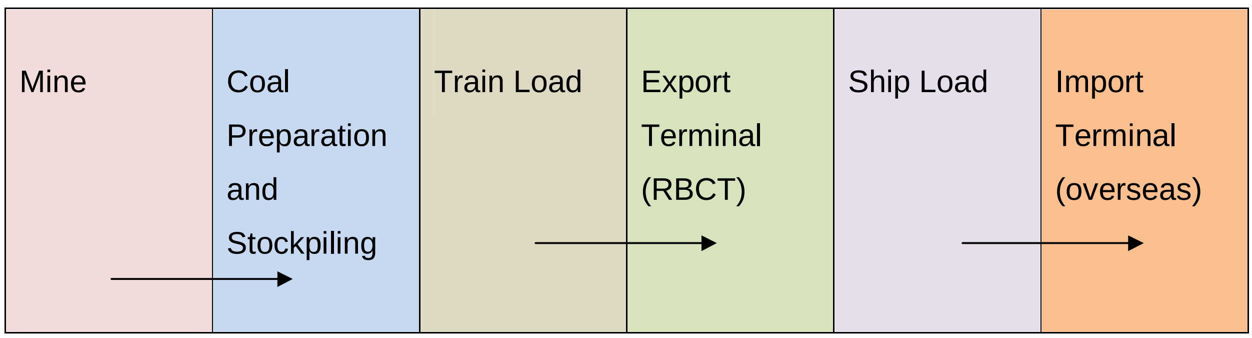
Figure 4-5 South African Coal Supply Chain (Domestic)



Source: own model

Figure 4-5 has three main levels: coal mine (including beneficiation and stockpiling); transportation (conveyor belt, rail and road); and the customers (power plants, SASOL, industry and traders). Most of the South African coal customers are also the users (power stations, SASOL and industry). Only a very small volume of South African domestic coal is handled by traders.

Figure 4-6 South African Export Coal Supply Chain



Source: own model

The supply-chain stages are the mine/colliery – preparation and stockpiling – train load – export terminal – ship (to overseas customers).

Presently, most of the export coal comes from the Mpumalanga coalfields and the coal rail runs from Witbank to Richards Bay Coal Terminal. At the terminal, coal is stockpiled at various bays allocated to each exporter before being loaded onto the ship for export.

4.8 SUPPLY-CHAIN COLLABORATION WITHIN THE COAL-MINING INDUSTRY

Currently, the Chamber of Mines of South Africa provides a platform for collaboration within the coal-mining industry. It coordinates the tripartite partnership with mining companies, government and labour. Collaboration is between mining houses, ESKOM, labour, government, universities and various research and funding organisations driven by Coaltech, a research company operating under the Chamber of Mines (Coaltech 2009:5).

The Coal Rail Infrastructure Master Plan (CRIMP) in Queensland, Australia was developed to inform role players of the scope, cost and timing of investment required in the coal supply chain to support industrial growth. Through the CRIMP process, the Queensland Rail collaborates closely with access seekers, port operators and rail operators to determine the optimum rail-system solutions to match proposed port capacity increases. Other investments to improve system efficiency and/or increase system throughput are also investigated. Details of expansion for each rail system based on specific below the rail infrastructure expansion projects and associated above rail investment required to meet the future predictions, are also provided (Van Der Klauw 2009:15).

The impact of the rail infrastructure expansion projects on existing operations is measured via ‘Below Rail Transit Time %’ (BRTT %). The expanded projects are required to provide the additional throughput capacity while maintaining BRTT % below limits that are set for each system. This ensures that additional rolling stock is not required for existing contracts. The CRIMP also guides the Queensland Rail Network's investment approval and project delivery processes by providing the demand/volume trigger points, sequence for expansion projects and the target date for completion. The CRIMP then informs the coal producers of the projects which require endorsement through voting process (Van Der Klauw 2009: 17). The role players in the South African coal mining industry are both public and private entities with the public being more dominant through the ownership of land, sea ports, rail, locomotives and rolling stock (TRANSNET 2009:2). The government also owns the electricity company of South Africa - ESKOM, which consumes about 50 percent of the coal produced in the country (ESKOM 2009: i). Private ownership in the coal supply chain comprises the mines and the coal export terminal at Richards Bay (RBCT) (DME 2009:15). In other countries, for example Australia, a bigger role is played by the private sector in joint ownership of the rail and port infrastructure (Van Der Klauw 2009:15).

4.9 LOGISTICS AND THE SOUTH AFRICAN MINING INDUSTRY

The Council of Supply-Chain Management Professionals (CSCMP: 2000-2010:1) defines logistics as:

> "The part of supply chain management which plans, implements and controls the efficient, effective forward and reverse flow and storage of goods and services and related information between the point of origin and the point of consumption in order to meet the customer's requirements". (CSCMP: 2000-2010:1)

According to Quayle and Jones (1999:85), logistics is the process which co-ordinates all activities within the supply chain from sourcing and acquisition, through production where appropriate and through distribution channels to the customer. The goal of logistics is the creation of competitive advantage through the simultaneous achievement of high customer service levels, optimum investment and value for money. The term 'logistics' was originally used in the military to describe the organising and moving of troops and equipment (Smuts 2008: 33).

Logistics is the process which creates value by timing and positioning inventory. It is the combination of a firm's order management, inventory, transportation, warehousing, materials handling and packaging as integrated throughout a facility network. Integrated logistics links and enhances collaboration of a supply chain as a continuous process and optimises connectivity (Bowersox, Closs & Cooper 2007:4)

The goal of logistics is to link the market place and distribution channels to procurement and manufacturing in order to maintain competitive advantage. Its benefits include accrual of cost reduction, sales generation, improved service level and productivity (Bowersox, Closs & Cooper 2007: 257). Therefore a logistics mix can be summarised as planning and marketing strategy, purchasing, production planning, storage and materials planning, warehouses and stores, transport, customer service and technical support (Quayle & Jones 1999:87).

Logistics complements the supply chain through strategy, design and execution. Supply-chain design entails strategic functions involving chain members, its length, breadth, locations, systems and relationships (Waters 2007: 42). The logistics functions as provided by Waters (2007:43-44) include:

- procurement and purchasing: preparation and sending purchase orders to the suppliers;
- inward transport or traffic (inbound logistics): moving materials from the suppliers to the manufacturers;
- receiving: checking and accepting products in the organisation;
- warehousing or storekeeping: safe stock-keeping for latter dispatch on request;
- stock control: control and regulation of stock levels of inventories, procedures and patterns of purchase;
- material handling: moving materials within an organisation;
- order picking: preparing delivery loads for transportation;
- outward transport (outbound logistics): delivering goods to customers;

- physical distribution management: actual delivery of finished goods to the customers (downstream operations);
- recycling, returns and waste disposal (reverse logistics): reverse logistics or reverse distribution entails bringing various types of materials (damaged, bad packaged, wrong orders and so on) back from customers; and
- communication: coordinating flows of information and money.

(Waters, 2007:43-44)

The Council of Supply-Chain Management practitioners (CSCMP: 2000-2010: 1) provided estimated logistics costs as a percentage of gross domestic product (GDP) in 2004 for some of the world's leading economies: U.S. (12 percent), U.K. (12 percent), Italy (13 percent), Netherlands (13 percent), Japan (13 percent), Canada (13.5 percent), Portugal (14 percent), Denmark (14 percent), Taiwan (14 percent), Germany (14 percent), Hong Kong (14.4 percent), Ireland (15 percent) and Mexico (16 percent) (Rushton, Coucher & Baker 2006:11).

The estimates indicate great variations in the estimated logistics cost as a percentage of gross domestic product of some of the globally developed and slightly or medium-developed countries. It appears from the above examples that the logistics costs percentage is lower in the more developed countries than the emerging economies. For instance, the United States and United Kingdom are 12 percent compared to Mexico 16 percent and Ireland 15 percent. However, South African logistics cost to GDP in 2006 was 14.6 percent (Van Dyk, Ittmann, Marais, Myer & Maspero 2008:93). According to CSIR (2009: 5), the South African logistics costs relative to the GDP in 2008 was R339 billion or 14.7 percent.

4.9.1 Stockpiling at the coal mines

Stockpiling at the coal mine is done in two phases: coal excavated and brought to the ground mixed with overburden, then coal stockpile with coal with overburden removed and discarded. Hence stockpiling replaces warehousing in the coal-mining industry due to the bulky nature of the excavated material and the equipment used for bulk handling. After coal is removed from the ground, rocks are sorted out and dumped as solid waste. The coal free of rocks is delivered to the power station while coal for export undergoes the beneficiation process before it is transported to the export terminal.

At the sea-port terminals there are facilities for coal stockpiles where the coal is stored and sorted before it is shipped for export. ESKOM power plants had a stockpile of 20 days consumption during the winter of 2008 (ESKOM 2008:59). This stockpile level was inadequate and was one of the constraints which contributed to power outages in late 2007 and early 2008. The other constraints were too much rain and increased export demand. However, Eskom was urged by the energy regulator - National Energy Regulator of South Africa (NERSA) - to raise the stockpile level to 30 days (NERSA 2008:12).

Bulk handling of coal at the export terminal is a strenuous and expensive exercise. Expensive equipment is used. RBCT is the largest single export coal terminal in the world. In 2006, the terminal set a new world record by loading and exporting 409 809 tons of coal in 24 hours at an annualised rate of 149.17 million tons per annum (Mt/a).

RBCT is connected to the coal mines via Transnet Freight Rail (TFR) coal rail line. The facilities at RBCT include a quay 1.6 kilometres long with five berths and four ship loaders. RBCT coordinates with the Transnet National Ports Authority (TNPA) for the arrival and departure of more than 700 ships per annum. The terminal has a storage capacity of 6.7 million tons of coal and is serviced by six stacker reclaimers, two stackers and a reclaimer. When the new expansion is completed and the new facility launched in 2010, the handling capacity will increase from the present 72 Mt/a - 91 Mt/a, (*Coal International*, 2007:12).

Conventional warehouse use-management systems have been developed to enhance efficiency in managing the warehouse functions. The commonly used systems include barcode scanners, but Radio Frequency Identification (RFID) is slowly gaining prevalence in the industry. However, research on RFID is still continuing and will continue until it becomes economically feasible for massive commercial application. (Vogt, Pienaar & De Wit 2005:424-425).

Another system being introduced is 'computer-aided routing and scheduling (CARS), a distribution-planning system developed to handle various types of problems emanating from the distribution process. CARS use Geographic Information System (GIS) to facilitate the accurate address registration by marking the location site on the map. The data collected can be improved by using daily driver's reports or using geographic positioning system (GPS) to track vehicles and actual travel times' (Modares & Sepehri 2009: 13-21).Therefore, both RFID and CARS are ideal systems for fleet management. In the coal-mining industry supply chain, the two systems are ideal for all modes of transport.

4.9.2 Transportation

According to Bowersox, Closs and Cooper (2007:167-168), transportation performs two key roles in logistics: product movement and product storage.

> 'Product movement: the primary transportation value proposition is product movement through the supply chain. The performance of transportation is vital to procurement, manufacturing and customer accommodation. Transportation also performs a key role in reverse logistics. Transportation consumes time, money and environmental resources.

Product Storage**:** while a product is in a transportation vehicle, it is being stored. Transport vehicles can also be used for product storage at the shipment origin or destination, but they are comparatively expensive storage facilities. Since the main value proposition of transport is movement, a vehicle committed to storage is not otherwise available for transport. The transportation decisions are influenced by six parties: shipper or consignor, destination or consignee; carriers and agents; government; internet; and the public'.

(Bowersox, Closs and Cooper, 2007:167-168),

Transportation is a major component of logistics which can be categorised as either : inbound logistics, or outbound logistics.

Inbound logistics**:** is one of the five pillars of the purchasing processes in the value chain (Porter 1985: 39-40). The other activities include outbound logistics, operations, marketing and sales and services. These activities are related to receiving, storing and disseminating inputs to the product such as materials handling, warehousing, inventory control, vehicle scheduling and returns to suppliers (Porter 1985: 39-40). In essence, the role of inbound logistics is bringing the raw materials from the suppliers to the manufacturers and managing them until they are converted into finished goods (Van Weele 2003:10).

Outbound logistics:involves the activities associated with collecting, storing and physically distributing the product to buyers, such as finished goods warehousing, materials handling, delivery vehicle operations, order processing and scheduling (Van Weele 2003:11).

However, the two types of logistics are further complemented by Third-Party Logistics 3PL and Fourth-Party Logistics 4PL.

Third-Party Logistics (3PL): is an outsourcing process of using outside organisations to provide transport services previously performed in-house. The companies which offer such logistics services are known as ‘Third-Part Logistics’ 3PL providers. Virtually all logistics processes can be outsourced. The reason for outsourcing is basically that someone else can perform the same function more efficiently and economically than you can.

A survey conducted in the United States by Eye for Transport, 2005 & Logistics Institute, 2006, indicated that around three-quarters of firms outsource logistics. In the European Union the outsourced logistics market was valued in British Pounds at 176 billion in 2004 and projected to increase by about 45 percent out of all the logistics expenditure by 2008 (*Datamonitor* 2004). Some of the benefits of 3PL include lower fixed costs; expert services; combined work, giving economies of scale; matching capacity to demand; ability to deal with changing demands; increased geographical coverage and guaranteed service level (Waters 2007: 71).

According to Stroh (2006: 215), the frequently outsourced logistics processes are: direct transportation service (67 percent), customs brokerage (58 percent), freight payment (54 percent), freight forwarding (46 percent), warehouse management (46 percent), shipment consolidation (42 percent), track/tracing (42 percent), carrier selection (38 percent), order fulfilment (33 percent) and reverse logistics (33 percent).

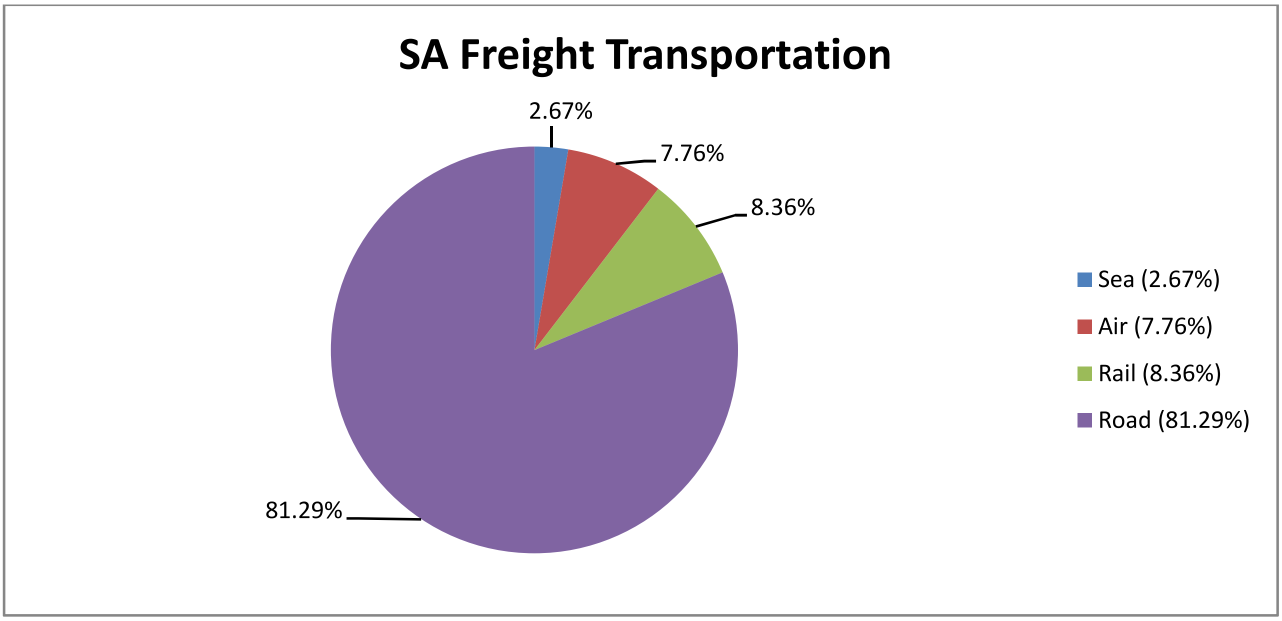
Fourth-party logistics (4PL)**:** involves an organisation which consults between a client and 3PL provider. However, it is paramount that a company conducts a ‘strengths, weaknesses, opportunities and threat’ (SWOT) analysis to establish reasons for outsourcing a logistics service requirement for its client. That means a company establishing its operational capability by measuring its strengths, weaknesses, opportunities and threats (Stroh, 2006:216).

Logistics requirements in the South African coal-mining industry supply chain are mainly 3PL comprising rail, road, conveyor belt and shiping for export.

4.9.3 South African freight transportation

The South African transportation operating costs in 2005 was 30.8 percent of the (GDP). Out of this 14.59 percent was the cost of freight transportation to GDP. The distribution of the freight transportation cost was: road (11.86 percent), rail (1.22 percent), air (1.12 percent) and sea (0.39 percent). These freight costs to GDP translate to road (81.29 percent), rail (8.36 percent), air (7.76 percent) and sea (2.67 percent) (DoT 2006: 5).

Graph 4-1 South African Freight Distribution Costs to GDP, 2005



Source: (DoT 2006: 17)

Graph 4-1 shows the South Africa's freight distribution costs to gross domestic product in 2005. The bulk of freight is transported by road (81.29 percent) followed by rail (8.36

percent), air (7.76 percent) and the sea (2.67 percent). This shows that there is a major opportunity to increase the rail freight transportation in the country.

The Department of Transport contracted a consulting company, Frost & Sullivan, to conduct a study aimed at reducing freight and passenger transport costs using all modes of transport and benchmarking with Australia. The aim was;

"to provide accurate and actionable information relating to effective operating costs of road, rail, air and sea transportation in South Africa and through benchmarking the best global practices, provide direction on short and long-term policy changes which will lead to the improved performance and efficiency of the country's transportation systems"

(DoT 2006: 199).

The recommendations from the consulting company Frost & Sullivan included inter alia:

- intermodal freight transportation to be promoted because it is cost effective and road/rail would use the existing infrastructure (it has been proved internationally). Intermodal (road/rail) entails the use of wagons that facilitate movement on both rail and road;
- introduction and promotion of public and private partnership (PPP) in the form of concessions or licensing or use of secondary lines;
- increase spends on infrastructure and skills development. Skills shortage was seen as the leading problem of doing business in South Africa in 2006 contributing 19 percent of all problems;
- introduction of transportation regulatory authority covering all modes of freight and passenger transport to ensure comparability of performance measures over and across modes.

(DoT 2006: 17-26)

4.9.3.1 South African rail network

The rail operation in South Africa is regulated by the National Railway Safety Regulator Act (Act 16 of 2002) (NRSR Act) with the establishment of the regulator in 2004. According to TRASNET 2009: 125), 'the roles of the Railway Safety Regulator include: overseeing rail operations and safety performance; and monitoring and developing regulatory requirements in terms of NRSR Act'.

The South African rail network is operated by the state corporation TRANSNET through one of its business units Transnet Freight Rail (TFR). 'The TFR uses the national rail network comprising 22 000 kilometres for freight transportation of which 1500 kilometres comprises heavy haul lines for export coal and iron ore. The rail network connects the ports to the hinterland of South Africa and the Sub-Sahara region. Services are primarily provided to customers in the mining, manufacturing, agriculture, forestry, automotive and intermodal sectors of the economy across the border trade and six African countries' (TRANSNET 2009:124).

South African rail freight is determined by the structural change in the economy from "a mining to a manufacturing focus". 'The main cost drivers in the rail freight industry include the long distances of transporting goods (minerals) from the mines to the ports and the massive labour costs as a percentage of the total operating costs. However, TRANSNET has an organised and efficient way of moving coal, iron ore and other resources, but the process of moving manufactured goods is still inefficient and unreliable. Mining haulage involves transportation of coal, iron ore, manganese, chrome, timber and other mineral resources. Moving of manufactured goods involves transportation of cement, fuel, chemicals and fast-moving consumer goods (FMCG)' (DoT 2006: 50).

'The South African Department of Transport (DoT) *Strategic Plan for 2010 to 2013* aims to make freight among other types of transport efficient and sustainable to the economy. This would enhance the Accelerated and Shared Growth Initiative for South Africa (AsgiSA) through collaboration of infrastructure development in transport, energy, mining, telecommunication, information technology, agriculture and Public Works' (DoT 2010: 2).

The rail freight focuses on two corridors for mineral transportation: coal link and OREX. Coal link: transportation of coal from Mpumalanga to Richards Bay. OREX: The focus here is on the transportation of iron ore from Sishen in the Northern Cape to Saldanha Bay, a distance of 850 kilometres.

According to (TRANSNET 2009:124) the rail freight company focuses on some critical operational issues that include:

- sustained safety improvements;
- executing customer demands;
- locomotive and wagon efficiency improvements;
- review of operational processes to lower costs and the creation of better efficiencies; and
- re-deployment of people-capacity to enhance operational performance, training and better skills to ensure a steady a steady movement towards best practices.

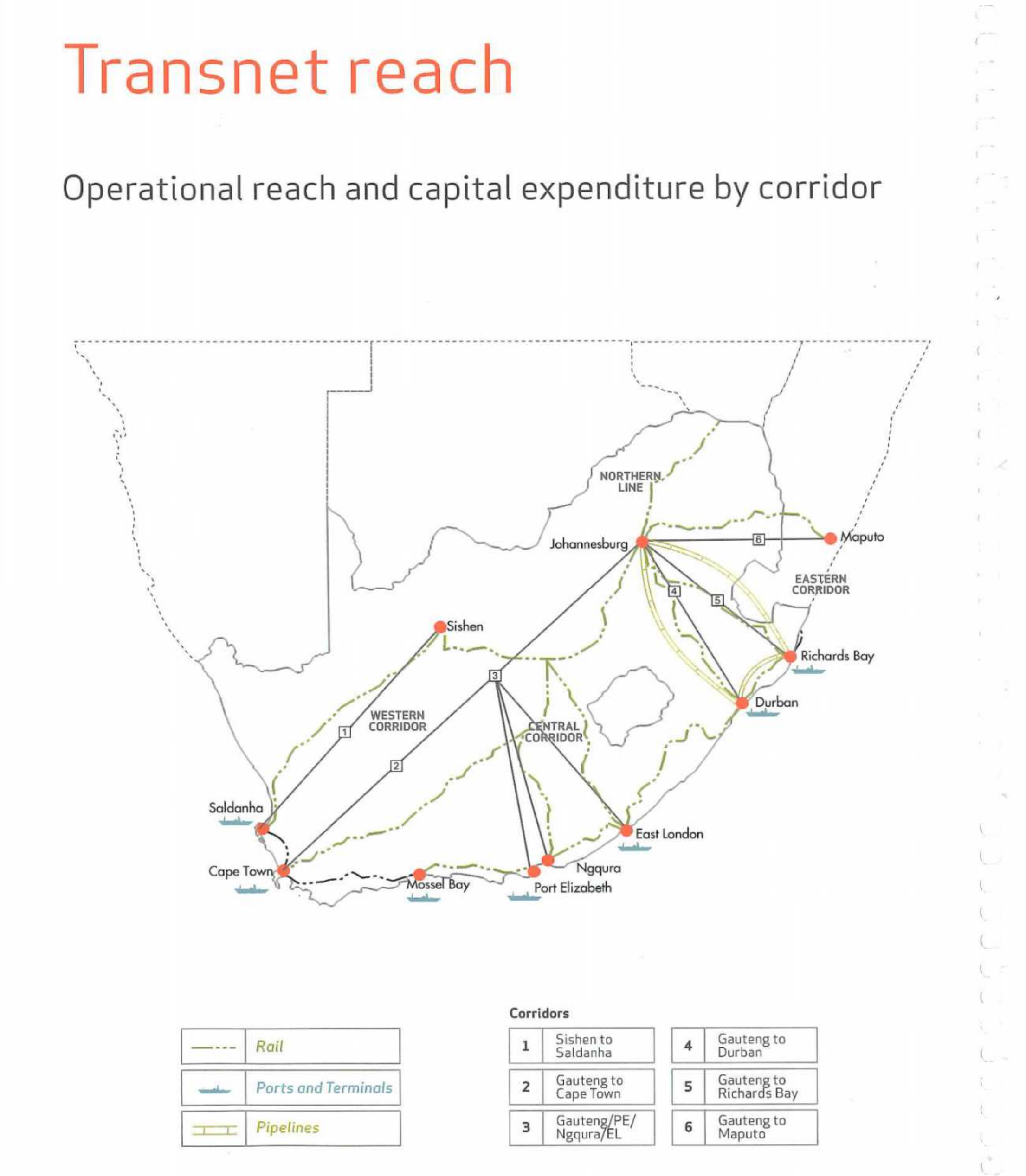
(TRANSNET 2009:124)

Rail transport is not as flexible as truck transport, but it is relatively cheaper, particularly for large and bulky products over long distances. It has a good historical record of safety and reliability. Rail shipment usually takes longer than truck shipping and is efficient in many ways (Lane 2010: 33). Other advantages of rail transport include the small space required for tracks, the mode is environmentally clean, and locomotives are fuel-efficient and trains carry massive freight. Rail transport has some disadvantages that include the large investment required to lay tracks, and the long life of locomotives and rail cars results in a slow adoption of new technologies. (DoT 2006: 53). In North America and Western Europe, rail gauges are of standard size that accommodates all the trains.

There is no standardisation of rail gauges in other countries, making it difficult to integrate railway systems between those countries. However, variable wheel spacing technologies have made it possible for some trains to transfer from one gauge to another (Finch 2008: 541).

Map 4-1 shows the South African national rail networks including the six corridors.

Map 4-1 South African Rail Network



Source: Transnet, 2008:6

The South African rail network map highlights the rail network, pipelines, ports and terminals. Also included in the map are the six rail corridors: Sishen to Saldanha; Gauteng to Cape Town; Gauteng/Port Elizabeth/ Ngqura/East London; Gauteng to Durban; Gauteng to Richards Bay Gauteng to Maputo. Some of the most remarkable rail lines include: Saldanha oil rail line; Witbank-Richards Bay coal line (650 kilometres); Sishen iron ore line (900 kilometres) and general freight line for cement and general goods.

Transnet is conducting feasibility studies for the expansion of the export coal line. The objective of the expansion would be is to increase throughput capacity, initially to 81 Mtpa and thereafter to 91mtpa. The company has plans to add 250 locomotives and between 12 000-15 000 wagons in order to reduce maintenance costs and to ensure efficient utilisation of remaining assets. (TRANSNET 2009: 127).

4.9.3.2 South African road transport

The truck transport is the most flexible mode of transportation since road infrastructure exists almost anywhere goods need to be delivered or picked up . South Africa has one of the finest road networks in the world (Crocker 2010:34). Road freight haulers are in two categories – full truck load (FTL) carriers and less than truck load (LTL) carriers. Full truck load carriers deliver products in full truckloads and usually transport goods from the manufacturers to the warehouses or distribution centres (DCs). Less than truckload carriers specialise in smaller and mixed loads. They utilise a network of terminals to consolidate freight originating from different shippers into a single truck. This mode of transport is more expensive than FTL (Finch 2008:541-544). The total land transportation in South Africa comprising the road and the rail usage, accounts for approximately 90 percent of the total transport with road comprising 66 percent of the market share.

According to Lane (2010:33), road transport has advantages over the rail in that there is accessibility (road network available in most places), competition (resulting in improved service, reliability, operations, equipment and competitive pricing) and perceived use for cross-subsidisation,

Road freight has a competitive advantage over rail freight as the South African roads are maintained by the government, whereas the state owned corporation TRASNET is responsible for maintaining both the fleet and the rail tracks. South Africa has a national road network of 754 600 kilometres. Table 4-1 shows the national distribution of the road types (DoT 2006: 80):

Table 4-1 South African National Road Network, Department of Transport, 2006 (Kilometres) kms

Road Infrastructure Measurements	Distance and Units (2006)
Total road network	754 600 km
Surfaced national roads	15 600 km
Surfaced provincial roads	348 100 km
Un-proclaimed rural roads	222 900 km
Metropolitan, municipality and other roads	168 000 KM

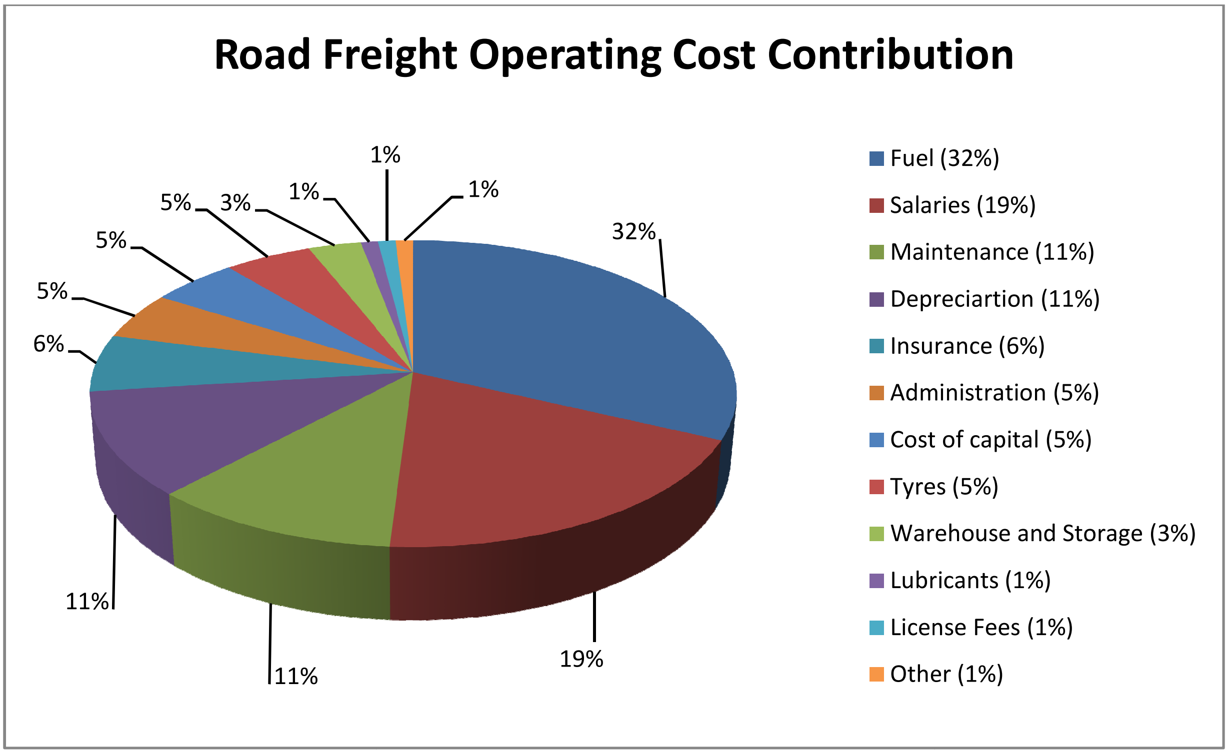
Source: DoT 2006: 80

South African road freight moved 1037 million tons of freight in 2004, translating into 2.74 percent of the gross domestic product (GDP). The road freight costs comprise the resources (operational, regulatory and infrastructural) consumed with the objective of delivery (export and import). This total cost expenditure includes costs incurred in-house and those outsourced. The total costs comprise fuels, salaries, license fees tyres, insurance, lubricants, depreciation, costs of capital, warehouse/storage, maintenance, administration and other costs.

The South African road freight operating cost is made up of fuel, salaries, maintenance, depreciation, insurance, administration, cost of capital, tyres, warehouse and storage, lubricants, and license fees, among others.

The graph below indicates some of the major road freight operating costs contributions:

Graph 4-2 Road Freight Operating Cost Contribution



Source: DoT 2006:84

The major South African road cost drivers are fuel costs, salaries, vehicle maintenance and insurance.

<u>Fuel costs</u>: about a third of road freight cost is on fuel, hence, the use of fuel-efficient vehicles is paramount. To curb the persistent fuel price hikes, vehicles operating on ultra low sulphur diesel (ULSD) are being used.

<u>Salaries:</u> over 19 percent is spent on salaries. The salary spend is high due to high medical insurance bills which the operator has to carry due to the high impact of

HIV/AIDS on its employees. The operators are also under pressure from the trade unions to provide better (higher) salaries to their employees.

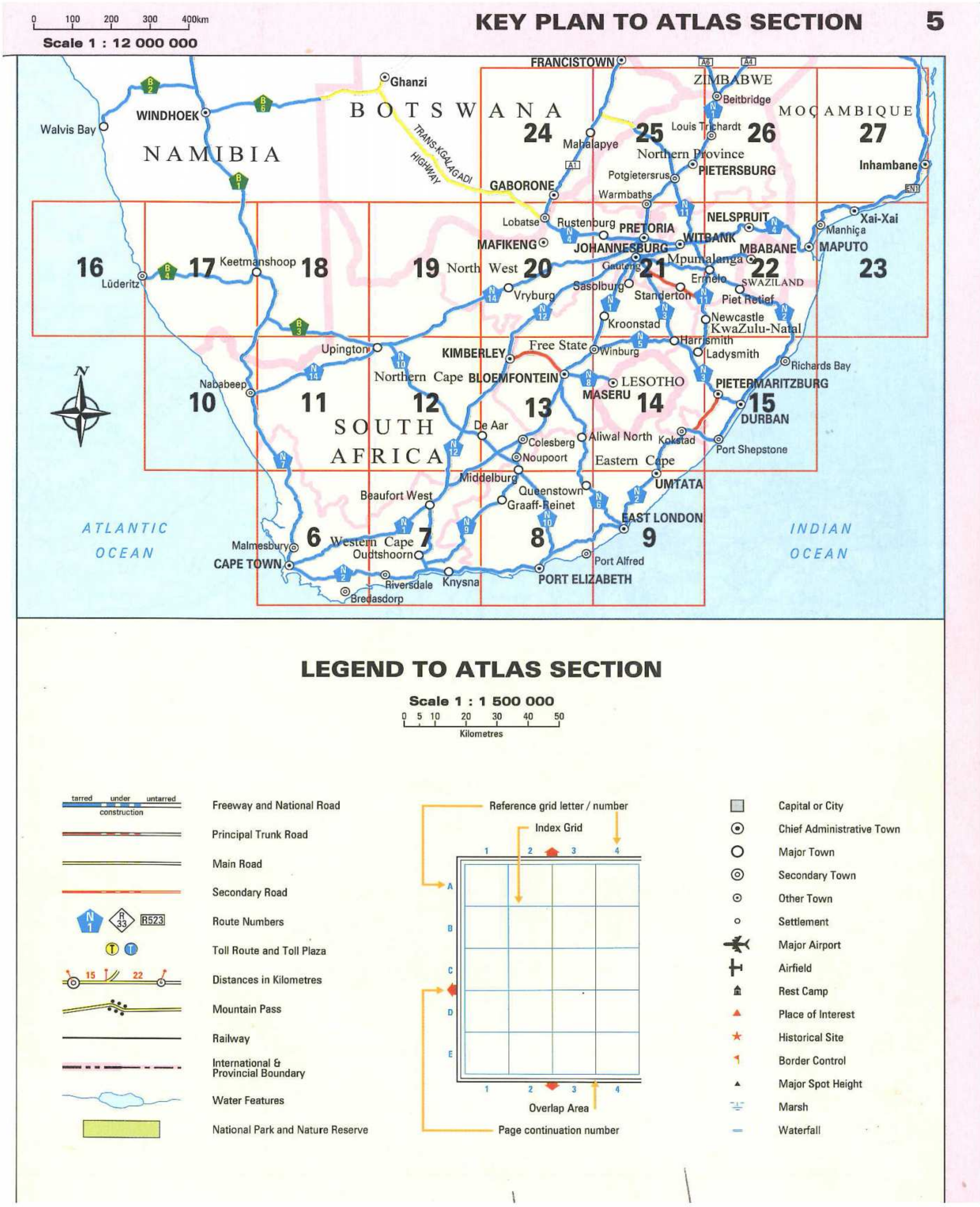
Vehicle maintenance**:** over 11 percent is spent on vehicle maintenance. This high cost of maintenance is driven by the shortage of diesel mechanics in the industry.
Insurance costs**:** over 6 percent is spent on insurance. The high rate of insurance is due to calculations based on the total national road freight accidents estimated at approximately R23 billion per year (DoT 2006:87).

The road freight business in South Africa was deregulated in 1991 and presently dominates the freight industry with a market share of 83 percent of the freight business. The remaining 17 percent is shared between rail, air and sea. Using a 33 ton truck for over 140 000 kilometres the road freight cost is calculated to be R18.18 per kilometre (DoT 2006:90). Hence, there is opportunity to grow the rail haulage business in South Africa.

Deteriorating road quality can potentially have negative effects on the vehicle and on the national economy. Increased maintenance and repair costs lead to increased vehicle operating costs for transport operators. The increased operating costs are either absorbed by the vehicle seller or transferred to the consumers. South African roads are divided into three categories: primary, secondary and tertiary road networks. The primary road network is owned by the South African National Road Agency (SANRAL) and is generally in good condition. The secondary road network is not in a good condition and requires constant maintenance (CSIR 2010:25-29).

Map 4-2 indicates the South African national road networks: primary, secondary and tertiary. It shows how the roads traverse through cities and towns from the coast to the interior, highlighting freeways, national roads, principal trunk roads and important landmarks like the capital cities , airports and other places of interest in the country.

Map 4-2 South African Road Network



Source: Map Studio, 14th Edition .

The South African road network map shows all types of roads in the country and how they serve the corridors serviced by the rail network. Most of the national roads converge at Johannesburg, Gauteng Province which is the country's main economic hub. The map also shows the road connection to all the South African ports with cities and towns in the interior and the other Southern African countries: Swaziland, Lesotho, Botswana, Namibia, Zimbabwe and Mozambique. The N1 Highway runs from Cape Town through the Southern and Eastern African countries to Cairo, Egypt in North Africa.

4.9.3.3 Conveyor systems

Conveyor systems are for moving materials between fixed points, holding materials as a short-term buffer and for sorting. Both gravity and powered conveyors can be used for the movement of goods. Powered conveyors are normally used for longer distances There are various types: roller conveyors, belt conveyors (belts running on supporting rollers), slat conveyors (fitted with horizontal slats), chain conveyors and overhead conveyors. Conveyors are used in high throughput, fixed routes, continuous (or intermittent, but frequent) movements and on uneven floors or split-level operations (Rushton, Croucher & Baker 2006:300).

In the South African coal mining industry, conveyors are used to transport coal to a number of power stations in the Mpumalanga area as a number of them are built next to the coal mines. The coal-fired power plants are designed with a coal mine next to them for the ease of supplying coal in a system called a 'tied-colliery' contract These are long-term contracts meant to ensure coal supply security to the power stations. Even the two new coal power stations currently under construction are designed on this model with 40 years long-term coal supply contracts (ESKOM 2009: 65).

However, this study has established a few instances where this model is not applicable, for example in the case of Majuba power station whereby the coal mine designated to supply the station could not be used due to geological problems. So the power station's coal requirement is delivered from other mines by road and rail. Presently, some of the coal mines in the Mpumalanga coalfields are affected by coal depletion and are not able to produce enough coal to meet the power stations' capacity so road and rail transportation are used to deliver the extra coal from outside coal mines. For instance, the mine that supplies Tutuka power station produces only 50 percent of the power plant's coal capacity so the rest has to be delivered from other mines by road and rail (ESKOM 2009:226).

4.9.3.4 Marine transport

Marine transport entails transportation by cargo ship, containership, or barge and is typically the lowest cost per ton per mile, but slow and inflexible. 'There are two main types of shipping processes: 'breakbulk ships' and 'container ships'. The breakbulk ship carries pieces of cargo that fits the container while the container ship carries a full load of the specified cargo. Loading in this mode of transportation is usually slow'. (Finch 2008: 541-544).

Sea ports provide logistics platforms which manage, develop and adapt complete logistics in combination with production and sales (Sengpiehl, Oakden, Nagel, Toh & Shi 2008: 65). In South Africa, marine transport falls under the National Ports Authority (NPA), a business unit of TRANSNET. The National Port Authority controls all the 8 South African ports which include Saldanha Bay, Cape Town, Mossel Bay, East London, Port Elizabeth, Durban, Richards Bay and Ngqura. 'The National Ports Authority business is divided into two service segments: the provision of port infrastructure and marine services. Marine services include dredging, navigation aids, ship repairs and marine operations' (TRANSNET 2009:146).

South Africa is among the 15 top sea-trading countries in the world and accounts for about 5 percent of the global seaborne trade. More than 20 million containers passed through the South African ports in 2005. The port of Durban is South Africa's largest general cargo port and handles 66 percent of the country's container trade, and is the biggest container port in the Southern Hemisphere (DoT 2006: 95).

The South African port infrastructure is divided into five segments: containers, dry-bulk, liquid-bulk, break-bulk, and automotive. 'The containers are used to transport general cargo. The dry bulk transports bulky cargo for example coal, iron ore, aluminium and others. Liquid bulk includes cargo like oil. The break-bulk comprises containers which carry assorted cargo for different consignees. The automotive is for the shipping of motor vehicles. The major commodities handled at the South African ports are coal, iron ore, containers, vehicles and steel. There are 15 port terminals situated in 6 South African ports. The port Terminals provide cargo handling services for a wide spectrum of customers which include shipping lines, freight forwarders and cargo owners. Port Terminal operations are divided into four cargo sectors: containers, bulk, break-bulk and automotive. The container sector is the largest of them and contributes about 59 percent of the Terminal revenue' (TRANSNET 2009: 146-158).

The challenges the sea-freight industry experiences, as stated by (DoT 2006: 97), include: limited capacity hindering growth, the difficulty of attracting private sector participation and optimising the use of the port/terminals.

'Limited capacity hindering growth**:** lacking capacity in both water-side and land-side space is a constraint. As a result, only a limited number of containers can be stored at the ports and a limited number of ships that can be docked at any given time.
Encouraging private sector participation**:** South African port operations are undertaken by the state owned corporation TRANSNET and there is need for private sector participation but implementation has yet to commence.
Optimising use of terminals: there are instances of underutilisation of terminals placing unnecessary limitations on capacity. Such limitations include lengthy bureaucracy and slow customs processes, skills and personnel shortage and safety requirements (accidents are very rare in the industry)'.

The South African maritime industry has five types of supply chains: coal export supply chain, iron ore export supply chain, fruit export supply chain, motor vehicle supply chain (vehicle components import and built vehicles export) and general trade import/export supply chain. The maritime industry is to greater extent controlled by the government through TRANSNET which owns the rail and sea infrastructures including the land and waterways they lay. The private sector owns the products carried through the infrastructures. Hence, building a fully integrated supply chain would require maximum input from the government (Fourie 2005:58-61).

The South African leading coal export Terminal is the Richards Bay Coal Terminal (RBCT), with a handling capacity which has increased from 76Mtpa in 2009 to 91Mtpa in 2010. Marine transport in South Africa is mainly used for shipping goods into the country and for export as in coal and other commodities. (Chamber of Mines 2009:27).

4.9.3.5 Intermodal transport

Intermodal transport means that at least two different modes are used in moving the goods from origin to destination. Commonly found combinations of modes include marine/rail, rail/road, marine/road and marine/rail/road (Smit 2010:23). ‘In the rail/road intermodal system, the wagon is fitted with mechanisms which facilitates hooking to the truck and wheels to run on the rail. Intermodal transportation is the primary link between domestic transportation and international trade. In 2003, of the nearly 10 million trucks and containers that were moved by intermodal transport, half were associated with international trade’ (Finch 2008: 541-544).

‘A lack of intermodal facilities between ports, roads and rail is the main inhibiting factor for growth in the containerised traffic. For instance, TRASNET”s responsibility for port planning and management deters private sector investment and has resulted in a situation where several ports are in serious need of development, investment and modernisation, but are limited by provision of capital under the control of central government’ (Lane 2010:32).

4.10 CONCLUSION

The supply chain and logistics management were covered in this chapter. Details on supply chains and supply chain management, their design and planning were elaborated on. A typical supply chain model showing the stages of a supply chain was provided. The types of supply chain 'push versus pull' which include the customer-focused, process-centric and innovative types were elaborated on. The supply chain limitations were also examined .

A South African supply-chain model was provided showing the stages in domestic and export coal supply from the mine to the end-user/customers. The supply-chain integration and collaboration were also articulated. Logistics and its important role in the South African coal mining industry's supply chain was discussed and the various transportation modes used were listed as rail, road, conveyor and marine. Since South Africa does not have inland marine services except for water sports, marine is used for shipping export coal overseas. The maps of rail and road networks in South Africa were also provided.

The next chapter discusses the Theory of Constraints (TOC) and its application in the South African coal mining industry.

CHAPTER 5
THEORY OF CONSTRAINTS

5.1 INTRODUCTION

This chapter discusses the theory of constraints (TOC), its importance and application to the coal-mining industry to improve effectiveness, efficiency and profitability (throughput). The chapter will look into the origin of TOC, its effects on business, the relevance systems theory, thinking and approach, its application in supply-chain collaboration and plant classification. Other areas covered include the capacity management and throughput across the South African coal supply chain, demand management and the systems applications.

5.2 PERSPECTIVES ON THE THEORY OF CONSTRAINTS

The Theory of Constraints (TOC) is the holistic understanding of organisational operations, optimising in money-making (throughput) and profitability by maximising utilisation of bottlenecks/constraints in all the processes of the organisation (Goldratt Institute 2001-2009:9).The philosophy involves understanding the demand and capacity management of the organisation. The process commences with forecasting, which is driven by the demand history of the organisation. The TOC philosophy can be applied to all types of the organisation both non-profit and profit seeking. This chapter looks at the application of the Theory of Constraints (TOC) in the South African coal-mining industry supply chain.

The theory of constraints is part of operations management and provides an advanced perspective on capacity in the organisation. The essence of the theory is to consider capacity management when products or services flow along a chain of processes. The philosophy of TOC was developed by Eliyahu Goldratt in 1992 and is based on the recognition that almost all products and services are created through a series of linked processes. These process chains may be found in one organisation or spread across the organisations in a supply chain. Each process step has a specific capacity to produce output or take input as is the case with customers and in every case there is at least one process step that limits throughput for the entire chain. This process step is referred to as the ‘Constraint’ (Bozarth & Handfield 2006: 222).

The Theory of Constraints (TOC) is a body of knowledge that deals with anything that limits an organisation’s ability to achieve its goals. Constraints can be physical or non-physical. Physical constraints include processes, personnel, availability of raw materials or supplies. Non-physical constraints include procedures, morale, training and others (Heizer & Render 2008: 619). Bozarth and Handfield (2006: 222) liken the movement of goods through a process chain to the flow of liquid through a pipeline. If one has a pipeline with varying diameters at various sections (that is some wider and others narrower), then each section has a certain capacity analogous to the pipe diameter at that section. In this situation, the flow constraint is experienced at the narrowest section of the pipeline.

According to the Goldratt Institute (2001-2009:2), the core constraint from virtually every organisation emanates from the fact that organisations are structured, measured and managed in parts rather than as a whole. This results in lower-than-expected overall performance output, difficulties securing or maintaining a strategic advantage in the market place, financial hardships, failure to meet customer expectations and chronic conflicts between people representing different parts of the organisation. Hence, the constraint(s) constantly shift from one place to another.

The Goldratt Institute (2001-2009: 4-7) provides three processes used by clinicians to treat patients as: diagnosis, designing a treatment plan and the execution of the treatment plan. This process is similar to the diagnosis of problems in an industry.

‘Diagnosis: establishing the symptoms and using cause-and-effect to establish the cause of the problem (the disease).

Design a treatment plan: considering each patient's situation, a diagnosis is done to establish the problem and medication prescribed on that basis.

Execution of the treatment plan: based on the patient's diagnosis, a fitting treatment plan is developed to implement the treatment.

Identical procedures to those applied in healthcare are also used when applying TOC to solve problems in organisations. However, in an organisation one needs to look at three questions: What to change? What to change to? How do you cause the change?'

According to Heizer and Render, organisations need to follow the five step process pioneered by Goldratt to treat constraints:

> Step 1: identify the constraint(s);
> Step 2**:** develop a plan for overcoming the identified constraints;
> 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. Ensure that the constraint(s) are recognised by all those who have impact on them; and
> Step 5**:** once one set of constraints is overcome, go back to step (1) and identify new constraints.
>
> (Heizer and Render, 2008:619),

In order to understand the five steps of TOC, the Goldratt Institute has provided three important guidelines:

- understand all the processes involved in providing product or service;
- understand every factor involved in the production of product or service and the overall system performance; and
- ensure extra support and materials to enable the processes to maintain high performance consistently. (Goldratt Institute, 2001-2009:9)

Therefore, constraint management is a framework for managing the constraints of a system in a way that maximises the system's accomplishment of its goals. The fact that it manages the most important part of the system, the part which determines its output, means that constraint management is actually a way of focusing on the most critical aspect of the system (Finch 2008: 660).

5.3 THE RELEVANCE OF SYSTEMS THEORY, THINKING AND APPROACH

As part of operations management, TOC traces its background from the organisation's pursuit for optimisation. Operations management includes activities which relate to the creation of goods and services through the transformation of inputs and outputs. To create goods and services, organisations perform three functions, as stated by Heizer and Render (2008: 4): marketing, product/operations and finance/accounting.

'Marketing**:** generates the demand and takes orders for a product or service (sales).
Production/operations: creates the product.
Finance/accounting**:** tracks how well an organisation does in paying bills to suppliers (accounts payable) and collects money from clients (accounts receivables)'.

However, 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). Bottlenecks are common occurrences, because even well-designed systems are rarely balanced for a very long time without a mishap (bottleneck). A bottleneck is an operation which limits output in the production sequence. In a supply chain, bottlenecks occur when there is material or units accumulating upstream because the next operation has insufficient capacity to accept the load.

According to Heizer and Render some of the techniques of dealing with bottlenecks include:

- increasing the capacity of the constraint(s). This may require capital investment or more people and may take some time to implement;
- ensuring that well-trained and cross-trained employees are available to ensure full operation and maintenance of the work-centre causing the constraint;
- developing alternative routing, process procedures or sub-contractors;
- moving inspections and tests to a position just before the bottleneck. This approach has the advantage of rejecting any potential defects before they enter the bottleneck;
- scheduling throughput to match the capacity of the bottleneck (may mean scheduling less work at the work centres supplying the bottleneck).

(Heizer and Render, 2008: 620),

In order for organisations to meet the current competitive pressure, improvement must be effected; to "improve" means to "change". According to change is to:

- provide products and services that solve customers' problems;
- release products and services consistent with market demand;
- reduce variability in the process;
- have measurements that indicate success that relate to achieving the goals;
- reward people for their contribution to change.

(Goldratt, 2001-2003:2),

The TOC classifies products by the nature of their production, whether a single product is the only product from a production facility, or a production facility producing multiple products. The TOC plant classifications are described below:

5.3.1 TOC plant classification

Lepore and Cohen (1999: 43-57) cited in the website of Young 2003-2009 identifies four types of TOC plant classification: I-plant, A-plant, V-plant and T-plant.

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

A-plant (many-to-one): this 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, for example in the meat and steel industries. The constraints in V-plant is what is termed “robbing”, where one operation (A) immediately after the diverging point “steals” materials meant for the other operation (B). Once the final material has been processed by (A), it cannot come back and be run through (B) without significant reworking.

T-plant (many-to-many): plants that have multiple lines which then split into many assemblies. Most manufactured parts used are made from multiple assemblies and most assemblies use multiple parts, for example, computers. Both A-plant (synchronisation) and V-plant (robbing) constraints are experienced by this T-plant’.

Therefore, in TOC plant classification, the coal-mining industry can be classified as a V-plant (one-to-many) as individual coal mines produce basically one type of coal (brand) which has various or competing applications in electricity generation, petrochemicals production, steel production (coking), space heating (homes and industry) and export. Therefore, constraints in the coal mining industry are likely to be both internal and external, which Jiang, Zhou and Meng (2007: 6) classify as:

- internal: operational, quality, logistics, systems, skills, policies, staff morale; and
- external: in transport logistics, marketing, stockpiles, collaborations, legislation weather and environment.

Internal constraints in the South African coal-mining industry are found in operations and policy issues of the mines: the mining methods, employees’ skills (training) and the impact of management style on their morale as well as the systems used in the company.

External constraints in the South African coal-mining industry supply chain are found in transport logistics (supplies to the mines – inbound logistics) and coal shipment to customers (outbound logistics). Furthermore, the facility at the mine used for coal cleaning, blending (quality) and stockpiling; the coal marketing and the mine's collaborations with members of the value chain; how the law and legislations impact on the coal mining industry; and the over-flooding of mines during the rainy season resulting in wet coal which is difficult to burn. Viren, Andrew and Sreekanth (2006: 297-307) believe that mining activities contribute to environmental degradation through air and ground/surface water pollution, vegetation destruction, ground digging and earth removal and mine dumps of discarded coal.

5.4 THEORY OF CONSTRAINTS AND SUPPLY CHAINS

The Theory of Constraints in the supply chains looks at issues of supply-chain connectivity and collaboration within the value chain. The TOC application in logistics is also addressed. The impact and contribution of constraints to profitability and performance measures for those contributions to the value chain are evaluated.

5.4.1 Applying theory of constraints to supply-chain collaborations

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 end-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 (Simatupang *et al.* 2004:57).

According to Simatupang, Wight & Sridharan (2004:57-58) TOC comprises a set of three interrelated areas: logistics, performance measurements and logical thinking. Hence, when all the chain members in the value chain integrate and act as one company, performance is enhanced throughout the chain as the matching of supply and demand improves profit. In collaboration, individual firms are left to control approximately 20 percent and the remaining 80 percent of the operations is under the supply chain. Thus, joint decision making succeeds in creating a competitive advantage through collaboration in market access, better material sources and cost-effective transportation. The TOC aims to initiate and implement breakthrough improvement by focusing on a constraint which prevents a system from achieving a higher level of performance. The TOC philosophy states that every firm must have at least one constraint. The owner of a system is assumed to establish the business goal which is to make money now and in the future. The TOC encourages managers to identify the obstacles which prevent them from moving towards their goals.

According to Heizer and Render (2008: 620), the TOC application to logistics includes the Drum-Buffer-Rope (DBR) scheduling method to buffer management and is a means of addressing constraints in sales and marketing. The Drum-Buffer-Rope process entails:

Drum: is the physical constraint of the plant, work centre or machine or operations that limit the ability of the entire system to provide more. The beat of the system is the pace of production. Hence, the term ‘drum’ refers to maintaining operations and the beat of the drum is work-in-process.

Buffer: protects the drum so that it always has work flowing to it. Hence, buffers in drum-buffer-rope (DBR) are unit measures of production to monitor constraints in the system.

.

Rope: is the work release mechanism for the plant programming work into the system to maintain work-in-process.

Measurement entails determining whether the enterprise is accomplishing its goals of making money. Performance measurements include measures of throughput, inventory and operating expenses. A holistic process of supply-chain collaboration involves a five-step thinking process which includes plan, check, categorise, metrics and control, (Rushton, Croucher & Baker 2006: 215-217).

5.4.2 The constraints-based approach

Lepore and Chen (1999: 43-57) state that a constraint-based approach can be defined as a way of realising productive change to correct the negative impact of the constraint(s) on supply-chain profitability. The productive change focusing on actions of managing constraint(s) can directly contribute to profitability. This can be done in two ways: the lead member of the supply chain provides a reliable measurement of progress of revenue generation by the supply chain, and by focusing on the supply chain performance improvement. Citing Dettmer, 1998; Goldratt and Cox, 1992, Siamatupang *et al.* (2004: 61-62) identify the three measures used to establish whether or not the supply chain is accomplishing its goals of making money: throughput, inventory or investment and operating expenses.

Throughput (T) comprises revenue that a supply chain generates through sales of its products, less the truly variable costs of generating the sale. Such variable costs include the material costs, sales commissions, markdowns, and consumable supplies.

Investment (I) is all the money the supply chain invests in the work it intends to do, such as raw materials, finished products not yet sold and other work somewhere in between (work-in-process).

Operating expense (OE) is all the money the supply chain spends in turning investment into throughput. This includes direct labour, overheads and other fixed expenses which would be incurred even if it never produced a single product.

Hence for a "for profit" supply chain, the profit would be whatever keeps the chain members from generating more profits. Such chains have at least one constraint. The dilemma of supply chain collaboration can be resolved if the chain members can identify and focus their decisions on managing the few constraints which prevent them from making more profit as a whole, both now and in the future (Blackstone 2001:1053).

In the make-to-store supply chain, the constraint is often the end customers who come to the store to buy the product. This is analogous to the coal-mining industry where the situation is "mine-to-stockpile", which is the norm before shipment to the domestic or international customers. This point is elaborated under constraints in the South African coal-mining supply chain in other parts in this chapter. Customers need to be segmented along different dimensions, such as product features, availability, delivery time, quantity and price discounts and credit terms. This streamlines the order processing and makes it easier to pick up constraints within the chain (Simatupang *et al*. 2004: 61-62).

5.5 CAPACITY MANAGEMENT AND THROUGHPUT ACROSS THE SOUTH AFRICAN COAL SUPPLY CHAIN

The objectives of coal supply-chain management are to meet customer needs in quality and quantity. This entails the processes of the resource exploration, prospecting, exploitation (mining), preparation (beneficiation) and transportation. It is through these processes where constraints occur.

According to Jiang, Zhou and Meng (2007:6), constraints of coal supply chain manifest themselves in ways that arise from the fact that :

- most companies have not implemented the supply-chain concept theories;
- most coal companies are profit driven and overlook the cooperation and information-sharing with other members of the value chain;

- in many cases the employees are not well trained in supply-chain management; and
- constraints are usually experienced in transportation and resources.

5.5.1 Infrastructural constraints

The modes of South African coal transportation are conveyor belts, rail and road for both domestic use and shipment to the ports for the export market (DME 2009:39). Conveyor is the mode predominantly used for coal delivery to power stations. Road is also mainly used for the power station supplies, while rail is mainly used to transport export coal from Mpumalanga coalfields to the sea ports of Richards Bay, Durban and Matola coal terminal in Maputo, Mozambique (DME 2009:5).

As has been mentioned several times, the handling capacity at the Richards Bay Coal Terminal (RBCT) is being upgraded from the current 72 million tons per annum (Mt/a) to 91Mtpa in 2010. However,(and this is another point that has been mentioned before), this capacity has to be backed by similar capacity by TRANSNET which is yet to be implemented. There are some uncertainties regarding economic exploitation of additional improvement by Transnet (Prevost 2010:17). 'The RBCT budget for the Phase V extension was R1.1 billion and TFR would have to spend about R20 billion to meet the new capacity of 91 Mt/a. Transnet is conducting a feasibility survey to ensure that there will be enough orders from the current export markets in Europe and the prospective markets in Asia especially from India and China to meet the increased capacity' (DME 2009: 9).

'With the coal reserves depletion in the Central Karoo Basin (Highveld, Witbank & Ermelo coalfields), future large-scale mining will be concentrated in Limpopo coalfields of Tuli, Waterberg, Mabopane, Tshipise, Venda-Pafuri and Springbok Flats which has a total exploitable reserves of about 3.4 billion tons (11 percent of national reserves).
However, Limpopo Province has infrastructural constraints which adversely affect coal mining that includes scarcity of water (surface and below surface), roads, an inadequate

rail system and inadequate coal marketing. Eskom hopes to build more power plants in that region in future. On completion, the new giant Medupi power station, which is located in the Waterberg coalfield will be supplied by an Exxaro's Grootegeluk coal mine that is also situated in the same area' (Prevost 2009:6).

5.5.2 ESKOM- (Coal- fired power plants)

At the height of power outages in 2007/2008, the National Energy Regulator of South Africa (NERSA) special report in May 2008 listed some of the constraints at Eskom as being poor coal planning and procurement, wet coal and low stockpile levels. At the time of compilation of the report, the stockpile level was around 8 days (NERSA 2008: 38-39). The coal stockpile level increased to 20 days by the winter of 2008 (ESKOM 2008: 59).

Coal procurement and coal stockpile management was extremely difficult during the 2007/2008 period with both coal production and quality issues impacting on supplies to the power stations. The increased international demand for coal by India and China created export opportunities for local suppliers at international market prices. This resulted in increased pressure on both price and quality of coal supplied under contract. The power plants faced below-specification coals which in turn led to inefficient combustion and increased maintenance requirements. Coal production, delivery and wet conditions severely affected the organisation, which led to capacity constraints as of January 2008. Road conditions affected the shipments and ESKOM had to assist in road repair in some parts to facilitate coal transport and to cater for road safety (ESKOM 2008: 58-59).

'The critical solutions for ESKOM's constraints include ensuring a sustainable coal supply at reasonable prices, acceptable quality and flexible transport. The changes in the global market are placing ESKOM under increasing risk in terms of securing future supplies from the local market and at the same time the production capacity has not kept pace with increases in both local and international demand' (ESKOM 2008: 59).

5.5.3 TRANSNET (Transnet Freight Rail)

‘TRANSNET has budgeted for infrastructure projects covering 2010 for the next five years in order to meet the increased capacity demand. This investment is hoped to boost exports of coal and iron ore among other logistics requirements. The South African container system is predominantly road-based holding 85 percent of the market. Road congestion and the port’s ability to handle increased road freight will soon result in bottlenecks. TRANSNET views this as an opportunity and hopes to tap in on it’(TRANSNET 2008: 84).

Transnet has plans in place to expand the coal line capacity to 81 million tons per annum (Mt/a). The project will include the upgrading of the locomotives, repairs and replacing of wagons, upgrading running lines and improvement to infrastructure and signalling. Further increases in capacity to 91 Mt/a (depending on industry demand) is in the planning process and will be implemented as soon as the feasibility studies and contractual arrangements have been concluded with the industry (TRANSNET 2008: 85).

According to TRANSNET (2008:96-97), some of the infrastructural constraints are being addressed and others to be alleviated by the TFR on the coal supply chain include:

- Commissioning of 110 new electric locomotives for the coal export line to commence in the 2008/2009 period;
- the acquisition of mobile train simulators for training train drivers;
- increasing weekly coal transportation capacity from 1.445 million tons to 1.454 tons in 2007;
- focusing on efficiency improvements on key corridors including coal and iron ore exports;
- planning to integrate asset tracking systems (IATS). This system will, when implemented, enable real-time tracking of rolling stock, ensure visibility of

operations at NOC and ultimately provide information that can be relayed directly to customers regarding the progress of their consignments. IATS will also play a major role in safety support through the monitoring of speed and location of the trains;

- having already initiated the order to execute project O2E , which is a business process improvement project aimed at efficiency gains it is now anticipated that this project will in future simplify processes, clarify responsibilities, and accountabilities and improve communication concerning the handling of customer consignments. The project will ultimately contribute to increased volume throughput and asset utilisation;
- Improving customer contracting and developing ‘key account plans’ through a well trained sales force.

The TFR moved 67 million tons of coal in 2007 and 72 million tons in 2008 (TRANSNET 2008: 96-97).

5.5.4 Richards Bay Coal Terminal (RBCT)

Richards Bay Coal Terminal (RBCT) is the largest single export coal terminal in the world. It was opened in 1976 with an annual capacity of 12 million tons and it has grown into a 24-hour operation with exporting capacity of 72 Mt/a in 2008 and reaching 91 Mt/a in 2010 (DME 2009: 9).

According to (DME 2009: 5), the new capacity could by itself pose constraints in fulfilling its role due to a number of factors which include:

- production at the mines below capacity (Eskom 2008: 58);
- inadequate export orders (assumption);
- infrastructural: delays in building additional rail track and additional locomotives to meet existing capacity (TRANSNET 2008: 85);
- increased domestic energy demand (TRANSNET 2008: 82); and

- the inability to stick to the transformation plan: BEE companies are got a limited export allocation of 4 million tons in 2009.

5.6 DEMAND MANAGEMENT

Successful demand management involves coordination of the marketing and operations departments. According to Barnes (2008:151), demand management includes pricing, promotions, reservations and waiting.

‘Pricing: price mechanism to attract customers (in the coal supply chain, this means choice between spot and contract prices);

Promotions: advertising stimulates demand;

Reservations: as in service industries (airlines, hotels, lawyers and others);

Waiting: customers do not like queuing, but in certain circumstances the waiting process becomes acceptable, for instance, trucks queuing to be loaded or unloaded;

Alternative goods/services: offering alternatives like in transport or goods in different seasons’.

Pricing and promotion can increase or decrease demand or shift it to another time period (marketing strategy). This enables production to manufacture products based on demand. It also demonstrates the coordination between production, supply chain, marketing and manufacturing systems (Evans & Collier 2007: 545).

The aim of any capacity management is to meet customer demand over time. The output from an operation can be stored, while the excess inventory may be used to balance supply and demand over time. Producers will always want to devise a long-term plan termed an "aggregate capacity plan", showing how output and demand will be balanced over time. This may involve adjustment in supply (Barnes 2008:151).

In the South African coal supply chain the use of a long-term plan of coal supply to customers is used. Such a long-term plan is based on present and anticipated future demands for coal. The price for this plan (contract) is agreed at the time of the agreement. Looking at the case of such agreements between Eskom and the leading mining companies in South Africa, there are problems presently as both parties wish to revise the prices upwards as a result of increased cost of goods, machinery, production and services. These are the prices of coal supplies to ESKOM and the cost of electricity supplied to the mining companies and other heavy consumers of electricity for example in the metallurgy industry. These are constraints emanating from supply and demand.

Coal is bulky and the users are few for specialised applications for example power generation, liquid fuel production, and smelters (iron ore and aluminium) and export. The storage is yard stockpiling and transportation is mainly by conveyor belt for power plants, rail for export and some by trucks to power stations and other users.

5.6.1 Demand plan

A demand plan is an essential business tool for organisations and outlines the attributes which underpin effective and active demand planning capability. The demand plan enables organisations to meet customer needs swiftly and cost-effectively **(**Goldratt 2000-2010: 6)**. '**A forecast is a statistically based initial estimate of future demand. An accurate demand plan will help to deliver the product within customer lead time, deliver the right quantity of the right product, make sound operational decisions and ensure that financial planning reflects reality. Lead-time is the time required to deliver product to a customer' (Gattorna 2003:171-172).

Gattorna (2003:174) further elaborates on the implications of poor quality demand plans by stating that they are caused by poor customer service, excess inventory, excess production plan changes and increased distribution costs.

Poor customer service indicates that customers do not receive their orders on time and receive poor product/service among other things. Excess inventory means that production is done without proper demand plans resulting in extra stocks being unsold. Excess production plan change means having too many production plans that delay production resulting in added production costs. Increased distribution costs result from unplanned distribution by using inappropriate means of transportation.

Figure 5-1 shows the difference between a forecast and a demand plan

Figure 5-1 Difference between a Forecast and a Demand Plan

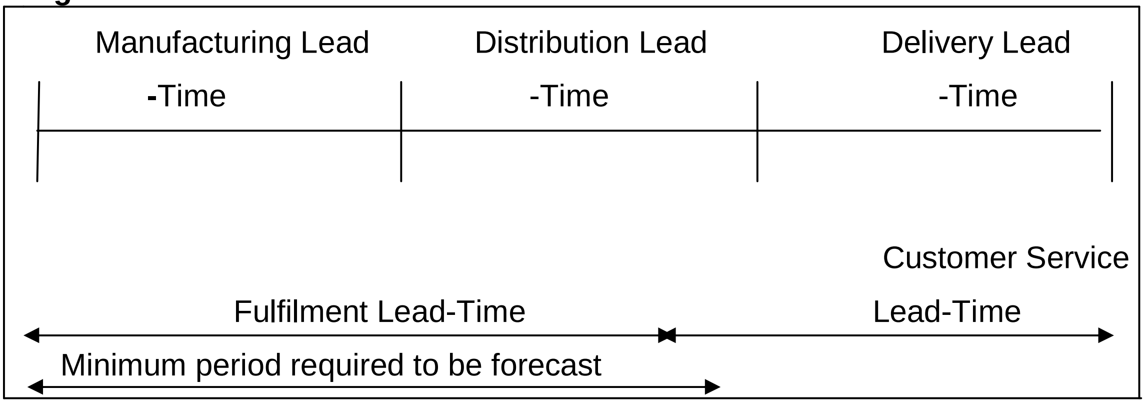
Forecast	→	**Demand Plan**
Statistically based		Based on the forecasts
Driven by demand-history only		Includes external factors.
		Result of a consensus review process

Source: Gattorna, 2003:172)

Figure 5-1 shows that the demand process commences with forecasting and forecasting is based on historical statistical data.

The forecast data including other factors comprising orders on hand help to make an effective demand plan. The demand plan ensures that the right product is made at the right time to meet the delivery lead-time.

Figure 5-2 Lead-Time Imbalances



Source: (Gattorna 2003:173)

Figure 5-2 shows the importance of timing at all stages from product manufacturing through distribution and delivery to the customer. The lead-times for all these stages are included in the demand plan. The forecasting time sets the pace for the appropriate lead-time at all stages upstream (manufacturing) to downstream (customer).

The implication of demand management plans and forecasting for the South African coal supply chain is critical in order to minimise constraints in the industry and increase profitability. Collaborations between the coal mines and the customers on demand plans for domestic and export coal consumption and transport logistics is paramount. The sensitivity of the coal use at power plants and industries requires timely delivery to meet the schedules for power generation and the running of industries in order to optimise throughput, output and profitability.

5.6.2 Forecasting and demand planning

Accurate forecasts are needed throughout the value chain by all functional areas of an organisation, such as accounting, finance, marketing, operations and distribution. An integrative database for all functional areas is used to help synchronise the value chain. A comprehensive value chain and demand software systems for example SAP integrates marketing, inventory, sales, operations planning and financial data. The SAP Demand Planning Module enables companies to integrate planning information from different departments or organisations into a single demand plan (Evans & Collier 2007: 440).

According to Evans and Collier (2007: 441), SAP Demand Planning offers the following capabilities:

- Multilevel planning: the ability of a firm to view and forecast products on any level and dimension;
- Data analysis: ability to analyse planning data in tables and graphics;
- Statistical forecasting: using past sales to identify the level, trend or seasonal patterns and to predict customer behaviour;
- Trade promotion support: generates promotion-driven forecasts on top of a baseline forecast that firms can model demand based on profitability goals or historical patterns; and
- Collaborative demand planning: this capability enables planners to share demand plans among key players in the value chain. Users can pilot collaborative planning processes and deploy them widely in the value chain. They can also collect, forecast and plan demand from multiple input sources.

In an important and sensitive industry involved in energy provision for the country, the South African coal mining supply chain requires effective forecasting and demand plans. This would not only be useful to the country, but also for the profitability of the members of the value chain. The global and local demand for energy has always been on the increase due to factors of industrialisation and urbanisation. Hence, there is need for effective forecasting and demand planning in the coal supply chain in order to achieve these critical goals.

5.7 SYSTEMS APPLICATION IN THEORY OF CONSTRAINTS

These are the systems instrumental in facilitating the smooth running of the supply chain from the point of materials supply through product manufacturing, storage, and distribution downstream to the customers/consumers. These systems are faster in detecting bottlenecks/constraints in the supply chain. Consequently, the constraints are alleviated to increase output (throughput) and profitability of the organisation.

5.7.1 Master Production Scheduling (MPS)

A Master Production Scheduling (MPS) is a statement of how many finished items are to be produced and when they are to be produced (Ioannou & Papadoyiannis 2004: 4928). Different industries use different MPS. For make-to-stock industries, a net demand forecast or after (on-hand-inventory) is used. If only a few final products are produced, the MPS is statement for the individual product requirements. For make-to-order industries, order backlogs provide the needed customer demand information, the known customer orders (firm orders), determine the MPS (Evans & Collier 2007: 559).

5.7.2 Materials Requirement Planning (MRP)

Materials Requirement Planning (MRP) is a forward looking, demand-based approach for planning production of manufactured goods and ordering of materials and components to minimise unnecessary inventories and reduce costs. MRP projects the requirements for the individual parts or sub-assemblies based on the demand for finished goods as specified by materials production scheduling (MPS) (Simatupang, Wright & Sridharan 2004:66).

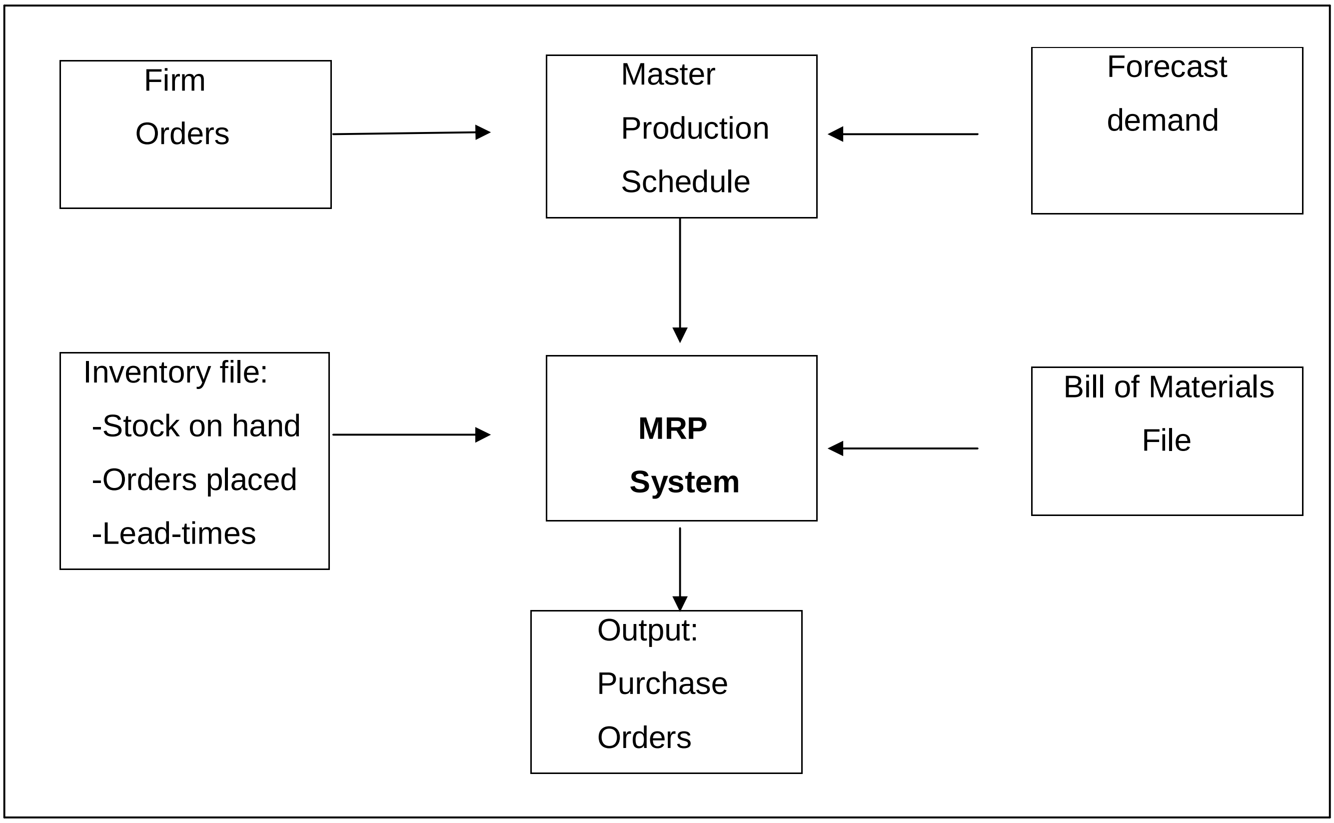
According to Evans and Cllier (2007:560), the primary output of an MRP system is the time-phased report which gives:

- the purchasing department a schedule for obtaining raw materials and purchased parts;
- the production managers a detailed schedule for manufacturing the product and controlling manufacturing inventories;

- the accounting and financial functions receive production information that drives cash flows, budget and financial needs.

MRP depends on understanding three basic concepts: the concept of dependence, the concept of time and the concept of phasing and lot sizing to gain economies of scale. Figure 5-3 shows the basics of an MRP system.

Figure 5-3 Basics of a Materials-Requirement Planning (MRP) System



Source: (Barnes 2008:253)

Figure 5-3 shows how the Material Requirement Planning System works.

Firm orders and forecast demand are compiled to make MPS which are then put into the MRP system.

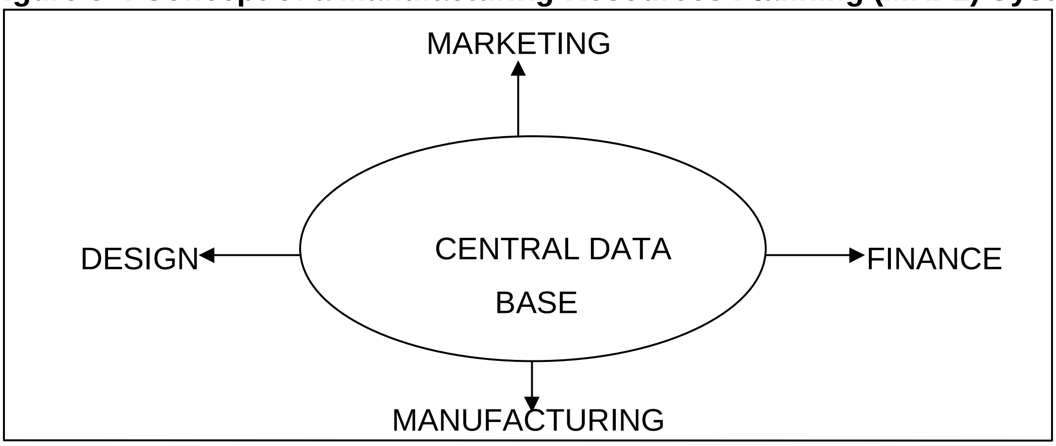
The inventory file comprising stock on hand, the orders placed and lead-time and all the materials required (Bills of materials file) are fed into the material requirement planning (MRP) system. After that the MRP system processes the purchase orders for the materials required for the product manufacturing.

5.7.3 Manufacturing Resources Planning (MRP 2)

Manufacturing resource planning (MRP2) is a computer based system of planning and control for manufacturing processes which extends the materials requirement planning (MRP) to include all manufacturing resources, and links the software for manufacturing planning and control to that of all other functions of the organisation via an integrated database. The MRP2 software acts as the central operations planning and control system. However, as with MRP, MRP2 will give inaccurate results if it is supplied with information which is not up-to-date. The system has been in operation for over twenty years (Barnes 2008:254).

Figure 5-4 shows the concept of an MPR2 system.

Figure 5-4 Concept of a Manufacturing-Resources Planning (MRP2) System



Source: (Barnes 2008: 254)

The above figure shows how the MPR2 system operates. It is supplied with data from marketing, finance, product design and manufacturing. The system uses the integrated data to process the requirements of the organisation in the four major disciplines indicated (marketing, finance, manufacturing and design).

5.7.4 Enterprise Resource Planning (ERP)

Enterprise Resource Planning (ERP) is a computer-based system for resource planning and control across an entire organisation. ERP is suitable for any type of business, services, as well as manufacturing for both profit and non-profit seeking organisations (Ioannou & Papadoyiannis 2004: 4932). The ERP system is actually an upgrade of MRP2. ERP has more operational capacity as its database also includes operations, Human Resources Management (HRM), finance, marketing, manufacturing and design. The ERP is expensive and there are only limited suppliers globally, for example the German company SAP and the US company Oracle (Barnes 2008: 254).

Ioannou & Papadoyiannis (2004: 4930) describe the methodology of ERP as follows:

- mapping of existing business functions and processes;
- determining the gap between the enterprise processes and ERP functionality;
- developing a prototype system including ERP functionality;
- installing System and 'Standard Integration Test Phase';
- tailoring the ERP for business processes not supported by the system (code development and ERP systematic enhancement);
- testing based on business scripts and IT conditions; and
- users training.

ERP enhances proficiency of most of the activities in the supply chain from the suppliers of raw materials (upstream) through the manufacturing and delivery of finished products through distribution centres to the customers (downstream). However, organisations still require a system to accommodate the missing link from ERP, the decision making process which can be achieved through use of Advanced Planning & Scheduling (APS) Systems. The functions of the system include: decision support tools for managing throughput; inventory and order/demand and modelling technology which enables the supply chain planning process to answer ‘what if’ questions, use of resource and capacity constraints; and optimising those constraints (Super Group 2005:18).

5.7.5 Optimised Production Technology (OPT) and the TOC

Optimised Production Technology (OPT) is a software system that is specifically designed for production scheduling. The OPT technology has promoted the managerial concept of the Theory of Constraints (TOC). Hence, OPT/TOC is a Production Planning and Control (PPC) method which attempts to optimise scheduling by maximising the utilisation of the bottlenecks in the process. Integrated PPC is a concept that uses planning methods in order to optimise the process (Davis & Heineke 2005: 618).

There are three major approaches to integrated PPC: push systems, pull systems and bottleneck systems.

Push system: A push system of manufacturing is one where goods are produced against the expectation of demand. Demand forecasting has to be carried out where raw material suppliers’ lead-times for delivery have to be considered. These forecasts are usually based on historical sales information. The problem arises in situations where either there is a higher level of demand than expected and sales are lost, or when there is a lower level of demand and finished product stocks grow too large (Rushton, Croucher & Baker 2006:183).

Pull system: A system of manufacturing where goods are only produced against known customer orders. This is because only actual orders from customers are produced on the production line. Therefore, firm customer orders are ‘pulling’ all materials through the process from the material suppliers up to the end-user customer. The use of Just-in-Time (JIT) in production is a pull system (Rushton, Croucher & Baker 2006:183).

Bottleneck system: A bottleneck applies 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 backlogs (both in terms of work-in-progress (WIP) and demand) (Davis & Heineke 2005: 619).

5.7.6 Inter-organisational Systems (IOS)

Inter-organisational systems (IOS) are defined as "automated information systems shared by two or more organisations". Inter-organisational systems promote the collaboration of organisations through electronic connectivity (e-business) which includes Electronic Data Interchange (EDI), Business-to-Business (B2B), extranet and electronic market places. IOS is becoming a competitive necessity due to globalisation and the growing importance of business alliances. In a study of 141 Israeli companies in 2008, Geri & Ahituv (2008:342-345) established the potential benefits of IOS as: strategic, transactional and informational.

Strategic benefits: includes enhancing or creating a competitive advantage, avoiding a competitive disadvantage, aligning with organisational goals and improvements related to customers, such as better service.

Transactional benefits: relates to operational efficiency, saving communication costs, improving productivity and shortening lead-lime.

Informational benefits: deals with improving information availability, quality and flexibility.

5.8 CONCLUSION

The importance of the Theory of Constraints (TOC) to all types of organisation in improving throughput output and profitability was highlighted in the chapter. In the organizations that do not make profit improvement of throughput, output is the criterion, while in a profit seeking organisations profit making is the criteria. The perspectives of the Theory of Constraints and the relevant systems theory, thinking and approach were discussed.

The application of the Theory of Constraints in the supply chains with reference to the South African coal-mining industry supply chain was provided in detail. This entailed the use of capacity management and throughput across the South African coal supply chain. The coal consumption in South Africa was also profiled both in domestic and export markets.

Collaborative Master Planning and the role of demand management and forecasting were articulated. The difference between demand planning and forecasting and the importance of the two functions to the supply chain were highlighted. The systems application in the demand planning, forecasting and other functions of the supply chain were discussed. The important roles played by the ERP in all the functions of the supply chain were also highlighted because it acts as a control system for the supply chain.

The next chapter discusses the methodology used in this study.

CHAPTER 6
RESEARCH METHODOLOGY

6.1 INTRODUCTION

The research methodology and sequential guidelines to this study are discussed in this chapter. The selection and profile of the participants, access to institutions and individuals are also discussed. The ethical and confidentiality undertakings provided to the participants during induction also form part of the chapter.

The methods of data collection, data interpretation and analysis, as well as measures of trustworthiness used, are also highlighted.

6.2 QUALITATIVE RESEARCH PARADIGM

This study adopted a qualitative research paradigm. Qualitative research provides insights which are drawn from the research in a natural situation, and aims to gain an in-depth understanding of a situation. The outcome of the qualitative interview depends very much on how much the researcher prepares the participants for the interview, a process called "pre-tasking" (Cooper & Schindler 2008:162-168).

According to Corbin and Strauss (2008: 302), qualitative research has substance, gives insight, shows sensitivity, is unique and creative in conceptualisation, yet grounded in data. It is research that appeals and stimulates discussions and further research on the topic. Conceptualisation entails having general ideas about a variable which has a part to play in one of the theories about human behaviour, organisational performance, or whatever it is that people are interested in (Lee & Lings 2008:150).

A paradigm is a philosophy comprising a belief system, world view or framework which guides research and practice in the field. There are three generally accepted research paradigms: positivism, critical theory and interpretivism (Willis 2007: 6). Lee and Lings

(2008: 372) describe a paradigm as a set of practices or methods used, for example questions asked, phenomena examined and interpretation of results of a particular discipline or research. Qualitative research methods are used more frequently within the constructivist paradigm as they are presumed to be better suited to investigate the truth (Donaldson, Christie & Mark 2009: 25). However, a phenomenological or qualitative research paradigm was used in this study.

Exploratory and descriptive design strategies were used in order to meet the aims and objectives of the study. Furthermore, an important characteristic of qualitative research is that the process is inductive in that researchers gather data to build concepts, hypotheses or theories rather than deductively testing theories or hypotheses (Merriam, 2002:5).

6.2.1 Exploratory

In the exploratory phase of management research, the researcher tries to establish a deeper understanding of the management dilemma and conceptualises ways of solving them. This is done by looking at the background information that could answer the research questions (Cooper & Schindler 2008:704). This study sought to explore the constraints in the South African coal-mining industry supply chain with a view to providing a model which would enable the industry to minimise such identified constraints.

'In qualitative research, respondents are made to relate to key stories and incidents which relate to the research topic. They experience their feelings, observations and opinions, and these provide insight into the topic' (Lee & Lings 2008:165).

\

6.2.2 Descriptive

According to Merriam (2002:5), ‘the product of qualitative inquiry is richly descriptive whereby words rather than numbers are used to convey the results of the study. Descriptive studies entail explaining the deep understanding of a situation (Lee & Lings 2008:247) and their objective is to portray an accurate profile of persons, events or situations’ (Robson 2002:59) .

Since this research is within a qualitative paradigm, it has strived to provide an in-depth understanding of the supply-chain constraints in the South African coal-mining industry. The constraints are established and a model to alleviate them is provided in chapter 8, providing more clarity on the research findings.

6.2.3 Inductive

An inductive approach is one which moves from specific observations to a more general theory. That is moving from the observations of the world to general theories about it (Lee & Lings 2008:7).

‘An inductive process means that the researcher approaches the field without a hypothesis or explicit framework. The strength of the inductive approach lies in a problem-solving focus, which increases the chances of problem-solving outcomes, or the chance for improvement and for identifying areas as important’ (Wadsworth, 1997:53).

Saunders *et al.* (2003: 389) state that the inductive process involves collecting data and then exploring them to see which themes or issues to follow up and concentrate on. This process is an inductive approach, which is the alternative to the deductive approach.

The focus of this study is solution-oriented in that it culminated in a model which could be applied in the coal-mining industry to minimise the constraints.

6.3 THE INTERPRETIVE QUALITATIVE RESEARCH TYPE

This is the output of the interview participants and the interviewer or what transpires after an interview in qualitative research. In using qualitative methodology to collect research data the researcher must not direct the respondent's answer through his/her tone of voice or rephrase the research question (Goddard & Melville 2005:*49).* The unstructured interviews enable the researcher to follow the unfolding events coming out of the interview and the participants are able to narrate the true picture of the situation being studied (Greef 2005: 296).

The researcher needs to be thoroughly prepared as he/she commences introducing the research project. Details of the methodology used requires to be noted and thorough consultation of the relevant literature on the research subject needs to be undertaken, Experts, which include members of the university research committee, appointed research promoters who adhere to university regulations in manners stipulated for conducting research need to be consulted. The other most critical issue for research includes being very careful to pay attention to details (rigour), truthfulness and ethical considerations (Bowen 2005: 210-219).

The methodology used in this research involved use of the relevant literature, consulting experts including members of the university the research committee and the research professor who provided guidance on conducting research at Vaal University of Technology. The researcher paid attention to details (rigour), truthfulness and ethical considerations while conducting this research.

6.4 RESEARCH DESIGN

Research design involves planning, preparations and execution of a research project.
The design process covers all the issues from theoretical reading, methodology, empirical data gathering, analysis and the writing process. 'The research processes

progress mostly through a circular process which involves revising and revisiting the original ideas and thoughts, revising plans, reading lists and rewriting the chapters'. (Eriksson & Kovalainen 2008:35).

Research design involves activities of 'collecting and analysing data, developing and modifying theory, elaborating or refocusing the research questions, identifying and addressing validity threats' (Maxwell 2005: 2).

In this study the research design covers a number of aspects. These include the selection of participants and inducting them into the research processes, introducing the participants to the interviews, undertaking the interview and obtaining feedback on the interviews for validity, and facilitating data collection in a recorded form using an audio- - digital data recorder. The recorded transcripts were transcribed and the data interpreted, evaluated and analysed by the researcher.

6.4.1 Selection and profile of participants

In qualitative research purposive sampling is often applied. The process aims to enhance understanding of the selected people or groups as they are selected for a specific purpose, task or expertise in research. The researcher should be in a position to expound the use of purposive sampling to instil confidence and a sense of validity for the research findings (Devers & Frankel 2000: 264-265). Purposive sampling is also called judgemental sampling. It comprises participants selected by the researcher based on their experience and knowledge of the particular research field.

Senior industry professionals and executives were used in this study hence, the use of purposive sampling was paramount.

Maxwell (2005:89) highlights the following four goals for purposive selections:

- receiving reliable representation;
- receiving data from the most relevant population for the study;
- deliberately examining theories that have started with or which have developed during the study process; and
- establishing comparisons from different participants to further enlighten the research findings.

This study used purposive sampling and in two instances , snowball sampling. Snowball sampling is a referral situation whereby a selected participant refers the researcher to other participants who are also eligible to be participants in the study. In two instances in this study, the participants approached first offered to have colleagues included in the interview to complement each other in providing in-depth answers to the research questions. This was an opportunity that enhanced the credibility of the participants' contributions.

The participants in this research were high profile officers who are all professionals in the coal industry supply chain. These professionals are senior managers from the organisations/institutions they represent and some of them are the chief executive officers. According to Neuman (1997: 205), purposive sampling is based on the researcher's knowledge of the research area and the important opinion makers within that research area. The researcher's knowledge of the South African coal-mining industry and the other role players in the industry enabled the researcher to approach the high profile people, including chief executive officers, to participate in the study.

There were 13 participants in the study who were drawn from 10 organisations/institutions. The participants were selected from the executive management and professionals from those organisations/institutions. In the three organisations, the participants were chief executives while the rest were senior professionals in the coal supply-chain management. Participants had on average 20 years of experience in their respective specialist fields.

Two of the organisations provided more than one participant in order to reinforce their contributions as they realised the importance and value of the study (credibility signal for the study). One organisation provided two experts and the other one provided three experts. One of the interviews was telephonic as the participant (a senior executive) was involved in frequent travelling around the country at that time publicly addressing some pertinent energy issues .

The organisations/institutions involved included:

A. five leading mining companies that produce over 80 percent of South African coal (4 of them participated in the interviews with 6 participants);
B. the leading South African domestic coal consumer that uses coal as primary source of energy for power generation. Two experts in coal logistics and coal supply-chain management participated in the interview;
C. the leading South African rail logistics company represented by a senior supply-chain specialist;
D. the leading coal export terminal represented by a top executive. The terminal is owned by the leading coal mining companies in the country.
E. the institution representing the interests of the mining industry in South Africa provided a specialist in the coal-mining industry;
F. the Government Department responsible for the Environmental Affairs provided an expert in environmental affairs; and
G. the South African regulatory body for energy was represented by a top executive managing the electricity generation, the bulk of it from coal.

6.4.1.1 Access to institutions

According to Eriksson and Kovalainen (2008: 54-55), when approaching organisations that the researcher is not familiar with (not known before), the researcher is required to prepare flexible agreements in advance that would appeal to all the parties (researcher and the organisation). In this regard, Eriksson & Kovalainen (2008: 54-55) provide the following guidelines:

- be very careful in introducing the research project;
- approach the right person most often the one who can grant the permission;
- send an e-mail indicating a wish to communicate with the person by telephone approximately a week before the interview (outline the study purpose to prepare him/her for the requirements);
- use appropriate sales skills;
- remember the audience for the outline that is sent is not academic nor research oriented, but more practical or business oriented; and
- let the company representative know “quickly and efficiently” about the relevance of the study, the kind of resources required from the participants, direct benefits to the company and about confidentiality undertakings.

The researcher must seek permission from the participants at the earmarked institutions to undertake the research and obtain informed consent to do so. Ehigie & Ehigie (2005: 622-623) ‘research is perceived as disturbing and a disruption without any foreseeable benefits in the short or long-term for the institution being studied. Therefore, it is important for the researcher to develop trust in order to create a working relationship with the institution’ (Flick 2003: 56-57).

In this study, the researcher was very careful in the choice of participants as very senior members of the organisations/institutions were used. Hence, the choice of communicating with the chief executives of the participating companies was important in order to secure the involvement of the decision makers. The researcher had a daunting task of selling the research story to the selected company senior executives through their personal assistants. That was the hardest part since the personal assistants are not technical and they had to buy into the research story in order to take it to their superiors. The medium of communication was telephone and e-mail. This task was successfully accomplished.

Clarity of the research objectives was addressed at the initiation stage as the researcher approached organisations/institutions' 'gatekeepers' by stipulating the value proposition for the study, purpose and the ethical considerations that also addressed 'informed consent' (admissibility for the research process).

6.4.1.2 Access to individuals

Permission to conduct research (informed consent) forms part of the strategy which requires written consent where appropriate, but oral consent is usually allowed for most business research (Cooper & Schindler 2008:37). The research participants have reservations of time and fear of probing questions, so the researcher needs to possess skills in negotiation and relationship building to overcome this barrier. When the interviewees gain confidence, a snowballing strategy may be used whereby interviewees refer their friends and colleagues for participation in the interview (Flick 2003: 57).

The initial introduction of the research project was not sufficient for some organisations to grant permission. They only consented after the researcher made a presentation wherein he clarified aspects of the study. The presentations were then followed by a signed consent. This was supported by the participants signing the research introduction letter from Vaal University of Technology which also contained confidentiality undertakings and assurance of the use of an audio-digital data recorder for recording the interviews to ensure accurate representation of the participants..

6.4.2 Data collection methods

6.4.2.1 Interviews

Data collection for this study was mainly through interviews with the selected respondents and in two instances there were referred participants. Unstructured questions (open-ended) were asked in order to elicit more information from the participants. In the two referral instances, the reasons were mainly to provide in-depth answers to the research questions. 'Unstructured interviews enabled the researcher to follow the unfolding events coming out of the interview and the participants are able to narrate the true picture of the situation being studied' (Greef 2005: 296).

In collecting data by means of interviews, the researcher should not direct or influence the respondent's answers through the tone of voice or the rephrasing of the research question (Goddard & Melville 2005: 49). The interviews were recorded using an audio-digital data recorder and transcribed. During the interviews, the researcher jotted down the important points in order not to interrupt the interview process. Immediately after the interview, the researcher drafted the field notes from the points noted.

The tools used for data collection in this study included: a questionnaire (using unstructured/open-ended questions), an audio-digital data recorder, pen and pencil (See Annexure 2 for an interview schedule).

Each interview was scheduled to last between 30-50 minutes, but some lasted much longer. There were two interviews which were postponed from the original schedules, but the rescheduled interviews proceeded without incident.

6.4.2.2 Recording the data

There are various means of recording data in a qualitative research project that may be utilised: taking notes; and using electronic devices such as a tape recorder, video recorder or digital voice recorder. The use of a digital voice recorder is ideal for data storage and retrieval in the computer. Lee and Lings (2008: 228) cites Bryman (2004), for the three ways of taking notes during interviews namely: mental notes, brief notes in the researcher's field note book that is done discreetly to avoid distracting the audience and a full field report to be done soon after the interviews. 'Researchers may use cameras, audio tape or video equipment to record the interviews and observations. Afterwards, the recorded materials are transcribed from audio-visual format into written text format. The original recordings are held as reference material that could be consulted, if necessary, for certification of the accuracy of the transcripts' (Ehigie & Ehigie 2005: 622)..

6.4.2.3 Transcriptions

Transcription is an interpretive process from oral speech to written texts. According to Kvale and Brinkmann (2009:178) 'speech and written texts involve different language and cultural registers that is (translation from one form to another)'. Transcription is a transformational process, taking live conversation and changing this into a text format. However, 'transcripts are silent and static in that recording of the tone and emotive content of the verbal expression and the body language (gestures, facial expressions and posture) are absent' (Barbour 2008:193).

6.4.3 Data analysis

Qualitative data analysis entails translating the interviewee's speech into meaningful words that are spoken in answer to the interview questions (Lee & Lings 2008: 235). Willis (2007: 310) states that data analysis in qualitative research commences with a research question/problem and follows an introductory approach using the following steps:

1) data collection;
2) data analysis ;
3) gathering data on another case;
4) applying the model to the new case;
5) revising the model if necessary;
6) repeating step 1-4 over and over.

'Reading the interview transcripts and observation notes (field reports) are the first steps in qualitative data analysis' (Maxwell 2005:96). One should listen to the interview tapes prior to transcription in order to prepare for rewriting and reorganising the rough observation notes. When you read the transcripts you should make a summary of the main points that will help you classify the main categories and relationships (Maxwell 2005:96).

Content analysis involves reading research transcripts through a number of times, noting down the key points and identifying the themes emanating from the participants' story line (conversation analysis). The themes are then grouped into more manageable groups of sub-themes. Finally, a summary table of the main themes emanating from the participants' story is drawn up (Thorpe & Holt 2008: 116). A summarised analysis and coding of written texts that emanate from qualitative data analysis commences with coding. 'Coding entails condensing data under broad headings and sub-categories which allows subsequent retrieval for the purpose of comparison. The researcher may make use of data excerpts called '*in vivo codes'* (Barbour 2008: 293-295).

Devlin (2006:198) provides five steps in content analysis as follows:

- read the written content thoroughly, trying to establish the participants' views based on the research question;

- categorise each participant separately in order to be able to record the emanating themes and categories;
- make a summary of up to six categories that emerge from the participants' response to the research questions;
- define each category appropriately; and
- have a verification factor that anyone reading the definitions can reach a similar conclusion to a reliability level of at least 90%.

Hussey and Hussey (1997: 251-252) state that a content analysis process involves examining a document or other forms of communication such as audio or video, and classifying them into various coding units which are usually prepared in advance by the researcher.

This style of content analysis was used to interpret data in this study. The researcher analysed the research data transcripts until saturation point when themes continued emerging repeatedly from the transcripts. Three main themes emerged with a number of sub-themes. The research findings are articulated in chapter 7.

6.4.4 Validity and reliability (trustworthiness)

Truthfulness entails validity and credibility of information provided to an enquirer (Maxwell 2005:106). Guba and Lincoln (1994) stated that 'trustworthiness consists of four elements: credibility, transferability, dependability and confirmability. Credibility refers to whether those findings bear any relationship to the data one drew the findings. Transferability is about whether one can justifiably transfer the findings to any other context. Dependability or reliability is about how well a researcher can assure readers of his/her findings and the way he/she arrived at them from the raw social context. Confirmability refers to whether or not one can convince readers that, as a researcher, you were not influenced by biases either from one's own personal values or theoretical background' (Lee & Lings 2008: 210).

The use of unstructured questions in this study and instances where participants referred their colleagues for participation in the research interview confirms that there was a general perception that the study was regarded as being truthful and that the approach to this study was considered to be honest. The participants responded to the open-ended questions based on their knowledge and experience without promptings from the interviewer (researcher).

6.4.4.1 Credibility

Credibility is perceived as a quality that emerges on evaluation of information or research work by experts (Donaldson, Christie & Mark 2009:52-53). 'Research is considered credible when it recognises the views of those considered less powerful by having due regard for people in the research process, which makes research subjects less suspicious and engages them more honestly. It is also possible that by having one's views and experiences validated, research will be experienced as empowering, and thus increases the research subject's willingness to share' (Thorpe & Holt 2008: 30-31).

The value proposition for this research was communicated at the introduction stage to the selected participants who represented the leading players in the coal supply chain. They were made to understand that the purpose of the study was "to establish the supply-chain constraints in the South African coal mining industry", and also that their role in the study was important and appreciated in order for them to feel trusted with their contributions. The fact that they are senior professionals in the field of supply-chain management holding responsible positions in their respective organisations in the coal industry and/or related fields gives credibility to the study. They were also made to understand that this research was purposeful and not just a fact-finding exercise.

After the interviews, the researcher communicated with all the participants via e-mail, thanking them for their contribution and in some cases, clarifications were sent in by the participants with regard to some of the issues discussed during the interview. This was a portrayal of cooperation and credibility of the research process.

6.4.4.2 Dependability

Dependability depends on the participants' willingness to contribute credible, applicable and valid data which can be sorted out through triangulation (Hammersley 1987:67). 'A research account may be considered valid if it portrays the features of what it is intended to achieve and as its objectives stipulate' (Corbin & Strauss 2008: 292).

The consistent coal supply-chain accounts provided by the participants from the leading coal mining companies in the country and their role players confirms the dependability of the data collected. The accounts provided by those participants also tally with details contained in their respective companies' annual reports.

6.4.4.3 Triangulation

Triangulation entails using more than one source of information as referral to multiple sources provides more insight into the phenomena one is studying (Cooper & Schindler 2008: 185). Triangulation limits biases and limitations and allows one to have broader perspectives of the issues one is investigating (Willis 2007: 219). 'It enhances validity and makes one look at issues from different perspectives in terms of methods and analysis' (Lee & Lings 2008: 239).

Triangulation in this study was achieved through the use of senior company executives and professionals in the interviews, cross-referencing internal documents obtained from the organisations/institutions involved and participants' checking and debriefing after the interview.

6.5 ETHICAL CONSIDERATIONS

Ethical considerations are required in research in order to remove misconduct in science. These are ethical guidance and codes that must be adhered to by the researchers, academic institutions and organisations for maintaining integrity in their endeavour to display good conduct (Eriksson & Kovalainen 2008:68).

Ethics are standards of behaviour that guide moral choices about human behaviour and their relationship with others. 'The purpose of ethics in research is to ensure that no one is harmed or negatively affected by research activities. Unethical activities include violating non-disclosure agreements, breaking participants' confidentiality, misrepresenting reports, deceiving people, using invoice irregularities, avoiding legal liabilities and so on'(Cooper & Schindler 2008: 34).

Research must be designed in such a way that participants do not suffer physical harm, discomfort, pain, embarrassment or loss of privacy. Hence, 'it is the researcher's responsibility to explain the value proposition for the research to the participants and how their rights will be honoured and protected. In line with this the researcher will also obtain permission (informed consent) in writing or orally from the participants before conducting the research(Coopper & Schindler 2008:37).

The ethical considerations for this study were communicated to all the participants through the letter written by a Research Professor at the Vaal University of Technology who also introduced the researcher and the value proposition for the study to the prospective participants.(See Annexure 1).

The leading role players in the coal industry come from both public and private sectors which calls for a high level of ethical consideration in their relationship. The leading coal suppliers are also leading global resources companies and also in the government departments and institutions they operate in, compliance with a high ethical standard is called for if they wish to maintain their credibility. Citing the example of ESKOM when intending to raise electricity tariffs, the message is first communicated to the public through well organised forums, such as the print and electronic media forum and in meetings at various centres all over the country, to explain the intention of such increases. Such are the importance of issues of ethical considerations. Energy is a sensitive topic not only in South Africa, but also in the rest of the world because of its socio-economic role in society due to its rising demand and its impact on the environment.

6.6 THEORY BUILDING AND DEVELOPMENT

Models and theories are similar in application and both of them can be used to predict future events. However, a good model should be based on a solid theory, but a model is just a descriptive representation of the theory (Lee & Lings 2008:123). A model is a simplified representation of a system. Models provide research tools which other researchers can use. They are used as research tools because they are not expensive.

According to Goddard and Melville (2005:43), ‘some of the reasons for using models include: high cost of building the real thing; the real system cannot be experimented with, they are easier to use by researchers, and they can be used for forecasting’.

This study has produced a South African coal supply chain model which can be used in the industry to alleviate the bottlenecks/constraints established there.

6.7 CONCLUSION

The qualitative research paradigm methodology used in the study was discussed in this chapter. The research fields of exploratory, descriptive, inductive and purposive sampling were elaborated. The ethical considerations for the study, research design, selection and profile of the participants, access to institutions and individuals were covered.

The data collection methods used, which include interviews, field notes, companies/institutions' annual reports, the audio-visual recording process and transcription of the data were described. The data analysis and interpretation using the content analysis method were stated. The validity and reliability (measure of trustworthiness) were expressed through tests for credibility, dependability and triangulation.

The process of theory-building and development was undertaken which yielded a supply-chain model that would alleviate constraints established in the South African coal-mining industry supply chain.

The next chapter discusses data presentation, analysis and interpretation emanating from the empirical study.

CHAPTER 7
DATA PRESENTATION, ANALYSIS AND INTERPRETATION

7.1 INTRODUCTION

This chapter comprises data presentation, analysis, and interpretation of the interviews for the study. The profile of the participants is provided. The data were transcribed and content analysis used for the interpretation. The interpreted data were then analysed for themes emanating from the study.

7.2 PRESENTATION AND ANALYSIS OF DATA

The respondents' comments have not been edited in order to preserve their authenticity.

7.2.1 When asked to describe coal mining:

the following respondents replied in part:

Respondent 1

"If you sell to Europe there are all sorts of taxes and issues with the type of coal and the sulphur and ash and things like that. So that is why they are buying coal from us which we wouldn't use in South Africa because it is such good quality coal. And we use the far lower quality coal in South Africa in our power stations compared to what they do in Europe".

Respondent 2

"You know, as the coal mines are quite mature here, I will give you an example. In Colombia what gets dug out of the ground, let's say 30mt get dug out of the ground every year, 95 percent of that coal you actually just do some very basic processing, you just take the stones out, simple, 95 percent of what you dig out of the ground gets sold into the export market. Coal is that good.

Here you make the same effort so you dig 30mt out of the ground, but of that 30mt, because it is an issue of base and qualities of the base is going lower, so now we are saying, well about 50 percent of the coal. I have to wash it. There is a lot of processing I have to do, clean it up, wash it, and crush it whatever 50 percent I can send out to the export market. So this is the problem that inherently in South Africa coal is not as competitive as say Colombia from a coal mining point of view because you put the same effort in. I'm assuming it is same cost of mining a mine. So have to put the same effort in, but you are getting half the product compared to Colombia. And I mean, I think the sense is that the mining is a lot more complex because it's much more stratified – it has got more layers it seems – so it is not like – I love the example".

Respondent 3

"But then there is a lot of coal where there are thin very low quality coal seams. Because of the huge demand, especially from ESKOM, people have really gone into the mining of coal. We call them truck and shovel operations. You have little overburden, it is easy to drill and blast. You load it away with normal construction machinery. You drill and blast, you load and it goes off to ESKOM."

"Our coal quality is not wonderful. You would typically mine if you are lucky, here anything between I would say up to 21, 22 mega joules per kilogram. I don't even want to mention a hell of a lot. For export to Europe they need 27 mega joules per kilogram plus, they don't accept anything else. Some of them will only accept 28 mega joules per kilogram plus. So what you do is you break your coal into small fractions and then you upgrade it through dense medium separation. If coal has got a lot of ash it is heavier so you use a medium where the coal is pumped into the right fraction which is more carbon float. That is what you take off. That's the energy because people buy energy".

Respondent 11

"I mean that mine is only……it produces like 17, 17 million tons of coal a year, 14 is low grade that go to power station. Only 3 tons are quality for export. Whereas, in the Witbank coal base and a lot of mines it would be 50/50. So the balance is very different. You tend to mine the best coal first. So all the good coal, the best coal is gone. So now we are left with mining the more difficult coal. It is more expensive. It's harder to mine, it's got worse quality".

In commenting about the coal mining business in South Africa it was notable from the respondents that the cost of mining coal in South Africa compared to other countries remains relatively high and that closely related to that is the low quality of coal mined in South Africa. Thus the cost and quality of coal mining emerged as a theme on this question.

The cost and quality of coal in South Africa have not in themselves had adverse effects on the industry despite the increase in energy demand and cost effectiveness since the domestic market, particularly the power stations, burn low quality coal which is abundantly available. The high cost of mining to a large extent has to do with the geology of the areas where coal is found.

7.2.2 On the question of supply-chain constraints:

the respondents had the following to say:

Respondent 1

"We are lagging behind in terms of production where we should have been, and obviously it is mainly to do with all these DME constraints in terms of prospecting licenses and mining licenses. Otherwise ESKOM wouldn't have had a problem. There is not a lot of new mines on the horizon and the ones that are happening are all ones that's more replacing the existing capacity than adding capacity. The ones that are going to add capacity obviously are the ones that are going to be ESKOM linked, Kusile and Medupi. But when you talk export you will find that most of the operations that are coming on stream now is replacing existing capacity or capacity that might disappear in the next year or two".

The respondent added:

“When I talk supply chain you can argue that the fact that it’s not easy to get new mining license and prospecting licenses that would be a constraint in your supply of coal in expanding. You have got to go in, prospect and drill and make sure that there is sufficient coal. Once you have done that, then you’ve got to do the environmental impact study. So I wouldn’t say it is a constraint, I’m just saying that’s part of the process. So it takes a lot longer from the day that you’ve identified the place where you can mine until you get to the point where you start to mine now. Ten years ago that perhaps could have been two or three years sooner, now it is going to be three years longer mainly because of all additional things that you now have to do. Whether it is the environmental and legislation, water and all these sorts of people – the local people – all those things.

Nowadays you require what they call a “pollution-control fund” from the start of the mine which you have to contribute to so that by the day you close that operation, you have got funds to level the ground, to take away all the structures – whether it’s open or underground and restore it. Ja, there must be money as well. And you have got to prove that you are providing that money and that you’ve funds that you have to estimate of what is going to cost and you have got to prove that you have got money to do that.

Ja it doesn’t make it easy because they want you to put the money upfront, who has the money to put upfront into a fund that they are going to use maybe 20 years down the line”!

Respondent 2

“It worries me that to do mining properly is very capital intensive. It is not the right way to say it, it is not like you mine……… you develop a mine, you mine for 20 years. And then you close it. And then when you close it, you walk away. It’s actually, you’ve got that continual liability and monitoring”.

Respondent 4

“There are requirements for the environment in the Act in terms of section 40 I think – but the problem that we find is that the Department of Minerals is the person who promotes mining and the person who authorises the environmental

> management of that, which leaves us with a problem because of the player and the rule maker at the same time. The environmental Department as well as the Provinces are in terms of MPRDA [the] only commenting authority".

From the above comments, there is a current theme which happens to be a constraint from the point of view of respondents, namely the policy and legislative environment. The policy and legislative environment is one of the major constraints affecting the South African coal-mining industry as it lacks clarity in parts on tenure of mine ownership and a lengthy waiting period for licenses (exploration, mining and water). As a result, it has scared away new foreign investors.

The current mining legislation was cited by most of the respondents as a barrier to potential future new investors in coal mining. The legislation Mining and Petroleum Resources Development Act (MPRDA), Act of 2002 is claimed to inhibit the fast processing of licenses, among other issues. They claim that it takes a long time to obtain any of those licenses. Their claims were confirmed by a press release by the Minister of Mineral Resources who stated that the time for obtaining the licenses will be reduced by 50 percent in future. The minister stipulated that a mining license will be provided with a water license and it will take 6 months to process instead of the previous 12 months. Prospecting and exploratory licenses will be provided within 3 months instead of 6 months (Biyase & Speckman 2010:17).

Respondents further mentioned the following:

Respondent 1

> "I think the coal mining industry in South Africa is sort of like hanging in the air, it sort of wants to expand and obviously now with the pressure on electricity it is going to be difficult with the price increases because are you going to go for more power stations – which is very expensive. We are fortunate because we've now got one of them- Kusile is now a linked one and Medupi is for Exxaro so now they want to outsource these things and privatise them. People don't know, it's very uncertain when it gets to things and you don't know whether ESKOM is

going to knock on your door tomorrow and say (you can't export this anymore, you have to sell it to us)".

"With Richards Bay expanding and all these new shareholders and suppliers coming into play, how is that going to work out. Whether it is going to be a smooth transition and whether they have the coal which they say they have and all these things. And that's why, you know that's why TFR is so questioning things because they are not sure whether it's going to happen and it's going to happen the way everyone says".

Respondent 6

"As far as mining industry is concerned, for general freight to issue there is; where are the rails, which own the rail, who operates the rails, and what are your rates and your capacity. Of course those are the things from a logistics point of view, you can talk about and you will know probably far better than I do – in terms of what makes a rail system efficient.

We have messed it up because of not sufficient strategic thinking has gone into what is the macroeconomics or the model for this dedicated line in terms of its investments, ownership, operating efficiencies etc. TRANSNET is starting to take the risk of understanding the export market. It is not their business. They must worry about their reserves, is there a market? That is not their business. If that is what they want to, why don't they just mine? …

I'm telling you what I have heard and what I have seen and what I have known about the industry from past experience. As far as ESKOM is concerned with TRANSNET, very positive talks, "Ye let's work together", whatever, but no delivery. It's at least twice expensive to go on the road than it is on rail…It takes us four years to build a rail line which it takes us two years to make a decision and two years to build it."

Respondent 9

> "That's why I think the relationship between TRANSNET and the industry isn't on a great footing. It's improving now. I think we are collaborating rather than saying "that's your responsibility, my responsibility." It's in both our interests".

The above comments indicate a lack of shared vision within the coal-mining industry. One major player in the industry does not quite know what the other player has in mind. Thus lack of shared vision emerges as an important theme.

Shared vision in the industry is lacking as there is limited integration and collaboration between the private ownership of the mines and the government which controls the logistics of rail infrastructure which is crucial for the industry.

In describing the constraints further, the respondents replied:

Respondent 1

> "The constraints are fairly simple. When it gets to domestic supply because we also supply coal in the domestic market – it's TFR. It's the biggest issue. I mean you don't want to go road, you can say, "okay, we can put more on the road", then if you put more on the road then……I mean, one of the biggest environmental issues is probably the fact that so much coal gets moved by road. Because it just messes up the whole area, all the dust and all that kind of stuff, it's just huge".

Respondent 5

> "I mean we are facing both rail and road constraints obviously. The rail constraint is around performance of TFR – Transnet Freight Rail – they just haven't been able to get out of the starting blocks. So our constraints are – on the rail side – is that we do have a little bit of distance to travel to get to the rail and on the other side, TRANSNET's performance has not been up to par. We are not also

blameless. We have not dealt with the rail properly on the tippler side so ESKOM is not totally blameless”.

On the road side the bottlenecks has expected the road conditions which are very poor, the performance of our transporters is a bit all over the place because for a lot of our transporters, moving coal to ESKOM is not their main business.

Respondent 11

“I believe that a number of power stations in time will need to have rail deliveries. Otherwise it’s got to go on the roads and we will continue with the problems we are having at the moment. It’s messing up the roads, it’s dangerous, there is too much trucks, I’s environmentally not good.

But we have constraints on rail for ESKOM, export as well as domestic market. It would be good to actually have nothing on the road. Other than the merchants, some of the small businesses or retail businesses have traditionally always been done by road because it is not enough volume to justify, but the bulk volumes they really all [should] be on rail or on conveyor belts”.

Considering a few of the comments above, damage to roads came across as a strong theme as respondents described some of the constraints facing the coal mining industry. The bulk of the domestic coal transportation to the power stations is through conveyor approximately 70 percent of their requirements and the remaining 30 percent is shared between road (24 percent) and rail (6 percent). The constraints are realised through road and rail transportation as highlighted in the above paragraphs.

The use of road for transporting coal to the power stations in Mpumalanga has helped Eskom overcome a dilemma of meeting the energy demand in the short-term. However, the impact on the roads, environment and the communities living along the route is substantial . Hence, Eskom has plans to reduce trucks transporting coal in favour of rail in future. Therefore, the rail network in the Waterberg area is paramount in helping meet the future relocation of coal mines and power stations.

If the coal-fired power stations are to continue running at full generation capacity, top-up coal has to continue coming from outside mines and will continue rising in volume in time. The suppliers of this coal are the smaller mines that sell coal in the spot market which is more expensive compared with the long-term supply contracts. The transportation mode is road (an expensive and inappropriate transportation mode for a bulky commodity like coal). The road transport adds extra cost in road repairs and has adverse effects on the environment. In 2009, ESKOM spent R 535 million on repairing roads which transport coal to the power stations (ESKOM 2009: 58).

Furthermore, the depletion of coal reserves in the Mpumalanga coalfields is a major constraint for ESKOM and the coal mines. Due to increased energy demand, ESKOM has to buy top-up coal for the power stations from the spot market in order to meet the power station generating capacity. The spot prices, as mentioned above, are higher than the long-term contract prices and the use of road transport is more expensive, unreliable and has adverse effects on the roads and the environment.

Since the energy crisis of 2007/2008, ESKOM has had no other choice but to use road transport to raise diminished stockpile levels at the power stations which had dropped to about 7 days. At the time of the FIFA World Cup Tournament in South Africa in June 2010, the coal stockpile levels at the power stations had risen to 42 days. However, the damage to the environment, especially to roads around Ermelo leading to the power stations, remains high.

Respondents added the following comments when asked about constraints facing the coal-mining industry in South Africa:

Respondent 2:

> "So our biggest constraints today is the rail, it's the logistics train from the Witbank area down to the Richards Bay coal terminal. And in the meantime you have to stockpile at the mines – there is plenty of coal……plenty of coal, plenty of capacity but only 60 million tons can be moved. If the rail was suddenly 80 or 90 million tons, the next constraint would be you wouldn't have enough coal. So

if we are up at 90 million tons, then depending again on the market – if prices are high there will be more coal and if the prices are low people are going to make money. But once the rail was no longer a constraint, the port will be.

Looking at debottlenecking the rail constraints: and some of those are operational, so that means how you operate, how long the train stays in a certain place, how you couple the trains together, so there is whole lot of stuff around the operational stuff. There are some stuff that the mine can do in order to load more quickly for example, some stuff that the port can do like offloading the trains more quickly and to get the trains turned around.

Well today's problems and I can tell you for the next probably 10 years, the issue will be around TFR constraints. And we have only really talked about export market so far because that happens to be our focus. But to two thirds of our business is actually domestic".

Respondent 3

"Now you will find that even to Richards Bay, now I can tell you now, I did statistics, asked the guys to give me the stats for their coal shipment to Richards Bay over December, 33 percent of trains all load were cancelled by Transnet. And for reasons, we don't have staff, no locomotive, the locomotives are broken, we had a derailment, we had power problems, we had cable theft, we had railway breaking, all sorts of things. The 33 percent decline indicates an organisation that is in trouble".

Respondent 6

"Now the question is of course will be from a competitive point of view South Africa compared to some of the other exporting countries, with their own control and manage the rail systems, we in South Africa that's all state owned. The investment cycle and the investment timing and infrastructure development just takes so much longer. And not necessarily aligned with the business cycles. Example, you can look at what we battled with at ISKOR– we battled for five years to convince TRANSNET to expand the line. It took me more than two years just to negotiate a new expansion rail agreement with them".

> “As far as the mining industry is concerned, for general freight the issue there is , where are the rails, who owns the rail, who operates the rails and what are your rates and your capacity. Of course these are the things from a logistics point of view, you can talk about – and you will know probably far better than I do – in terms of what makes a rail system efficient”.

Respondent 10

> “Internally, the constraints could be available or turnaround of wagons and the rolling stock – the rolling stock would be the wagons and locomotives – the turnaround that is a constraint. The second constraint would be any infrastructure problems that we might face…And remember our infrastructure has got a legacy that is odd, it is narrow gauge, whereas in most of the other developed countries they have got the wider gauge, so they can move much faster on the wider gauge and they can actually carry much heavier axel mass compared to us. We are constrained by the fact that our infrastructure is probably one of the biggest bottlenecks because we have Cape gauge which narrow gauge, which gives us a lower axel mass”.

Also see comment by Respondent 5 on page 214 above.

Transport and infrastructure emerges as an important theme that respondents also raised as a serious constraint. The rail infrastructure is the responsibility of TRANSNET Freight Rail (TFR) a business unit of TRANSNET. Rail transportation of bulk commodities for example coal is more convenient and economical compared to the road transportation. There are not enough rail networks to supply all the coal-fired power stations, hence, ESKOM mainly makes use of trucks to supply them where there are no conveyors used or where the conveyors do not supply enough coal. On the other hand, ESKOM does also not have provisions for train off-loading at most of the power stations. Indeed, ESKOM’s future plans are to reduce road transport and increase rail usage.

Respondents expressed themselves further in the following way:

Respondent 1

"Skills are a major issue. But again, we talk about new operations now, not existing operations".

Respondent 3

"The other big constraint is skills. And you know it starts right down with our schooling system… Maintenance team, because they are now working with very sophisticated equipment, now you can't just take a guy that has just come out of his three years apprenticeship, tell him, here is your toolbox, bugger off and work".

Respondent 6

"Skills, if you think about these mines to be opened, all their mining engineers, geologists, mine managers, mine supervisors… There are skills that need to be developed and grown. And likewise in the rail infrastructure, the operations and logistics, it's just not there. They are big constraints, but the bigger constraint is the decision making process".

Respondent 9

"So they go overseas, artisans, the guys who maintain the system and those people have been operating with TRANSNET or the old 'Spoorwee' or Spoornet or whatever. Those guys have been with the company for twenty-thirty odd years".

From the above comments, respondents were convinced that the shortage of skills across the coal mining industry is one major constraint which also emerges as one of the themes. The data above indicates that skills shortage is a major constraint for the industry as the number that have left the employment in the industry for overseas positions – mining engineers, mining managers and artisans have not been adequately replaced to meet the present demands for the industry to expand. .

Skills shortages continue to affect the coal-mining industry and the rail transport. The industry continues to lose trained and professional workers by voluntary departures and poaching by other mining sectors for example Platinum and to mining companies in other countries mainly Australia, Zambia and Tanzania. The personnel on the move are mainly train and mining equipment drivers, artisans, engineers and mining managers.

Respondent 1"New entrants were favoured in the fact that they needed more coal, but unfortunately there were a lot of abuse of the fact that they had this demand and people charge an exorbitant price, so… And now the shoe is on the other foot again, so a lot of people – especially a lot of junior miners – got hurt because of that. Because they were riding on these high prices and all of a sudden those contracts and prices just disappeared".

Respondent 2

"The bigger picture of the Witbank area is you have got a lot of power stations and different coal resources out is drying up. They are running out. Over the next 10 years we are going to lose 40 million of capacity. We are going to lose as mines, because mine are resources, they…start or disappear. And as they start to disappear the power stations are going to be screaming for suppliers. So what happens is that coal has to come from different places, from new places".

Respondent 7

"If you look at the coal mining industry in the country, I mean we are quite clear they are quite centralised, they are all quite owned by a few conglomerates rather than private individuals also in terms of wealth generation through the broader community".

The above comments from the respondents indicate that a lack of fresh investors in the mining industry is a cause for concern and is thus viewed as a constraint. This constraint also happens to be one of the themes emerging from primary data. The lack of fresh investors inhibits industrial expansion.

The stagnation of the South African coal-mining industry is blamed on the legislative environment which is ambiguous and there are delays in exploratory, mining and water licenses. Coal mining is controlled by five leading coal-mining companies which produce over 80 percent of the total coal produced in South Africa. They also continue to develop their existing capacity by improving their existing operations as well as by building new mines. There are very few new coal mines coming on stream from new entrants, yet the energy demand is on the increase. ESKOM has planned for 40 new coal mines in order to meet the medium-term energy demand (Wilhelm 2009:7).

Respondents added the following interesting perspectives when asked about constraints in the mining industry:

<u>Respondent 1</u>

> "Richards Bay, but I mean, if we haven't been able to privatise a single power station up to now, how do they all of a sudden think we are going to privatise this line? It is one of the biggest profit earners in TFR".

<u>Respondent 2</u>

> "Because TFR is a state owned enterprise, is trying to pick up the importance on the radar screen of politicians and actually this has to be solved. The benefit of debottlenecking TFR, the benefits of export exchange, and the benefits of domestic coal is electricity generation".

<u>Respondent 6</u>

> "Now the question is of course will be from a competitive point of view South Africa compared to some of the other exporting countries, with their own, control and manage the railway systems, we in South Africa that's all state owned. The investment cycle and investment timing and infrastructure development just takes so much longer and not necessarily aligned with the business cycles. Examples, you can look at what we battled with ISKOR – we battled for five

> years to convince TRANSNET to expand the line. It took me more than two years just to negotiate a new expansion rail agreement with them.
>
> But TRANSNET needs to be managed on a return on investment. The TRANSNET Board needs to say, 'which investment do I make, where do I send my wagons because I have a contract with my shareholder'. The shareholder doesn't know what the implications of this line in macroeconomic development here. Because investment is just a contract with the supplier who delivers here, it doesn't take into effect all the subsequent industries that have been created".

Respondents seem to think that the fact that the rail and TFR (TRANSNET) are owned 100% by the state presents challenges. Thus ownership of the rail and TFR emerged as one of the themes in the study. The fact that TFR is a state corporation that adheres to the policies of the state has limitations on levels of integration and collaboration with the private sector coal mining.

7.2.3 On the question of environmental challenges:

the respondents replied as follows:

Respondent 2

> "I think there are many other environmental issues when it comes to coal mining particularly in this country, where it's a very mature industry, so we have a lot of mines of depleted reserves and when you have got depleted reserves you have got to look at your rehabilitation and you got to have a look at how you treat the water. So probably the biggest two issues we have are rehabilitation and water use – water treatment. So you know when it rains and you have got these big open pits…. Rehabilitation and water treatment are the major issues that come along with that".

Respondent 3

> "The environmental issues I can tell you, the big one is water. Every coal mine whether open cast or underground has water. You have to put that water

somewhere and when your mine close, it gradually fills up with water and then it become absolute mine drainage. So that's why we are spending, as I told you we spend a lot of attention on water treatment.

Now the other environmental problem that you have while you mine is dust. Especially in an open cast mine, you blast coal, you blast other rocks, it creates a cloud of dust. And every farmer around will complain that the peaches in his backyard is now not growing as big as they used to grow in his great grandmother's time".

Respondent 9

"You have to…environmentally you have to be very careful. Plus obviously sometimes coal has spontaneous combustion and sometimes coal sits there too long on a stockpile and it starts burning and that's when the authorities and the press get all excited. But it's just a matter of managing your stockpile areas very carefully. So a lot of it goes… a lot of attention is paid to that".

Respondent 13

"The environmental protection regulations in place require power generating companies to pursue clean energy technologies".

Environmental issues continue to inhibit the coal mining industry. In pursuit of sustainable development, coal is still important as a primary source of energy despite its adverse effect on the environment. The situation will remain unchanged for quite some time as there is no feasible alternative in a short time. Hence, high carbon environment will prevail, but as stipulated by the United Nations Framework Convention on Climate Change (UNFCCC) treaties – Kyoto Protocol, 1997 and Copenhagen, 2009. The world should be committed to the reduction of carbon emissions and move towards a non-carbon environment.

Coal mining affects the environment through ground degradation (soil removal and pollution), air pollution (carbon, dust and particulate emissions), water pollution (Acid Mine Drainage) and social (noise from mining equipment and vehicles). The coal mining companies have environmental policies in place and a number of them are committed to the reduction of carbon emissions through initiatives for example “cradle to cradle”. This means that companies have a “circle” of commitment in dealing with carbon emissions from manufacturing through distribution to the customers and recycling the damaged products.

The following table summarises themes and sub-themes which emanated from the empirical study:

7.3 THEMES AND SUB-THEMES EMANATING FROM THE PRIMARY DATA

The themes and sub-themes emanating from the primary data can be summarised as follows:

Table 7-1 Themes and Sub-Themes Emanating from the Interviews

THEMES	SUB – THEMES
Cost and quality of coal	• Low grade coal burnt by the power stations and in production of synthetic fuels. • Beneficiation done on export coal and coal used in the industry and merchants.
Policy and legislative environment	• Minerals and Petroleum Resources Development Act of 2002 (MPRDA). • National Environmental Management Act of 1998 (NEMA).
Lack of shared vision with the industry	• Industry role players private and public. The coal mines are private owned and rail infrastructure is owned by TRANSNET (Government). Government policies differs from those of private sector inhibiting integration and collaborations crucial for supply-chain optimisation.
Transport and rail infrastructure - Rail and road transport are the major coal supply-chain constraints. -On rail transport, TRANSNET is the major issue due to inadequate capacity and internal operational problems. -Roads predominantly used to supply coal to the power stations. This continues to cause environmental damage and is undesirable for future coal transportation mode. -Junior miners holding the train for too long due to poor loading equipment. - Mistrust and poor communication between rail transport and the mining industry (Public and Private cohesion unlikely when infrastructure is wholly government owned)	• Rail major constraint- TRANSNET capacity not adequate (for export and domestic coal), old rail system, shortage of wagons, rolling stock and locomotives, skills shortage, lack of long-term contracts with mines, copper theft among others. • Road transport used by ESKOM to transport coal to power stations (environmental problems: air pollution, road damages, road accidents, social interruptions (noise) and others. • Conveyor used in tied-collieries to transport coal to power stations – about 70 percent coal is supplied to power stations via conveyor belts. • Diversity of decision making process at TRANSNET and the coal mining companies.
Skill shortage across the industry	• Mining engineers, mining managers, artisans, mining equipment and train drivers shortage experienced by the industry. Moved overseas and other industries. Training to cover shortage not realised yet
Lack of fresh investment	• Lack of new coal mining companies due to legislative environment (exploration, mining and water licenses delays), ambiguity of the mining Act and political scare (call for nationalisation of mines). Now a moratorium on licensing by Mineral

THEMES	SUB – THEMES
	Resources Minister (September 1- February 28, 2011). • Current landscape in a state of "flux" -initially fewer role players (major mining houses). -presently, economic slowdown and ambiguous legislative requirements with delays in licensing. • Future (legislation a major factor) -Carbon-constrained environment -Energy demand rising. -New coal mines to come on stream. • Relocation of coal mines from Mpumalanga coalfields to Waterberg coalfields, Limpopo. -Improved rail infrastructure to serve domestic and export market. -Relocation of coal-fired power stations from Witbank area when coal depletion becomes severe. -Reduce or stop coal transportation by road.
Ownership of the rail/TFR - TRANSNET	• Ownership of the rail by state corporation TRANSNET slows coal supply chain optimisation as proper integration and collaboration is lacking. Part private ownership would improve co-operation and enhancement of the coal supply chain.
Environmental issues: -A continuous liability to manage green environmental issues as stipulated by the legislative regulations, funders and social responsibility. -Role players sounded committed to "responsible environmental care" through actions like "cradle to grave" phenomenon.	• Current high carbon energy environment – carbon emissions, dust, noise, diesel pollution. -Coal transport trucks, road accidents, road damages, road congestion, community disruptions. • Commitment to functioning within a non-carbon environment. -"Circle" of commitment: "Cradle to Cradle" and "Cradle to Grave" -Building carbon credit through: -Reduction of carbon dioxide, -Re-use (products), -Re cycle. -Rehabilitate (soil, water and mines). -Research and funding.

Source: Own research

7.4 FURTHER FINDINGS OF THE STUDY

The South African coal-mining industry is well developed and undergoing transformation. It is in a “state of flux” as commented on by a number of the interview participants. The over 100 years old industry that started as a manual operation is now highly mechanised. The stagnation experienced in the industry is due to the increased energy demand from 2006/2007 and the few mines that have come on stream are small and have only replaced the existing capacity to the existing operations.

Coal mining in South Africa is still controlled by the big five mining companies that have been in operation for many years. They intensified coal mining after the transformation of ESKOM from hydro-power generation to the use of coal for power generation. There are 11 (eleven) coal mining companies that are registered members of the Chamber of Mines of South Africa and every one of them is running a number of mines. There are 220 coal mines in South Africa and 200 of them are situated in the Mpumalanga coalfields.

The five leading mining companies (Anglo Coal, BHP Billiton, Exxaro, Xstrata and Sasol) produce over 80 percent of the coal produced in the country. The four of them (Anglo Coal, BHP Billiton, Exxaro and Xstrata) supply 70 percent of the coal consumed by ESKOM’s coal-fired power plants under long-term coal supply contract referred to as a “tied-colliery”. It refers to the coal-fired power stations that are built over the coalfields with every one of them tied to a coal mine (colliery) to supply coal via conveyor belts, hence the use of terminology “tied-colliery”.

The fifth member of the “group of five” leading coal producers, “Sasol” has five mines in Secunda in the Highveld coalfields and produces coal for its processing plant into liquid fuels (Coal-to- Liquid, CTL) and petrochemical products and some for export. SASOL is the second largest domestic coal consumer, consuming approximately 18 percent of the total national coal production. ‘ESKOM coal consumption is about 50 percent of the national coal produced’ (ESKOM, PED 2009: 13).

The “group of five” coal producers are also the leading coal exporters and own the majority shares of the South Africa’s leading coal export terminal, Richards Bay Coal Terminal (RBCT). Many respondents expressed dissatisfaction and frustration experienced from the prevailing mining legislation as described in the interviews above.

The dropping capacity of the Mpumalanga mines due to coal reserves depletion is a big opportunity for new mines coming on stream. These are the old mines under the long-term coal supply contracts “tied-colliery” arrangements that have already started straining to meet the power stations generation capacity. Some of those mines have lost about 10 percent of their coal production capacity, hence ESKOM is forced to source coal from the spot market to top-up the shortfalls in order to meet the increasing energy demand. The top-up coal is supplied to the power stations by trucks. That is one of the reasons that there are so many trucks involved in coal deliveries.

The depleting of coal reserves from Mpumalanga coalfields and the increasing energy demand have prompted the mining industry to look for coal in the undeveloped Waterberg coalfields in Limpopo Province. However, for such development to take place, the infrastructure, which includes rail, road and water has to be put in place. TRANSNET has to build a new rail line and develop the existing line in order to have enough capacity to supply the power stations and export market route. The current export coal line is 650 kilometres long from Witbank to Richards Bay. This line will need to be extended to Waterberg which is a distance of about 1050 kilometres.

The trucks supply 24 percent (24mtpa) of ESKOM’s coal requirements. Out of this, 6mtpa are delivered to Majuba power station and the rest 18mtpa are top-up supplies to the other coal power plants. The giant Majuba power station is supplied from outside coal mines because its designated supply mine failed to operate due to some geological complications (mine too deep and has lots of gases).

Coal mining uses large volumes of water for the beneficiation process, so the water availability at Waterberg has been assured before the mining relocation. The location in the area of the new power station which is under construction (Medupi) is an indication of ESKOM relocating power stations there in future (ESKOM 2009:59).

The future of coal mining in a carbon-constrained environment is challenging. The current technology used for generating electricity from coal and other applications at SASOL for the production of synthetic fuels and petrochemicals will have to change in future to clean coal technologies. This is what the world demands today in order to reduce carbon emission that it is claimed to contribute to climate change (Abbott *et al.* 2009:88).

7.4.1 The South African coal mining industry's supply-chain constraints

The South African coal mining industry supply chain is in two segments – domestic and export. The domestic coal supply chain is dominated by coal supply to ESKOM followed by coal consumption by SASOL. ESKOM consumes approximately 50 percent of all coal produced in South Africa and approximately 68 percent of the domestic coal consumption (Chamber of Mines 2008:20).

The coal supply chain for the thermal coal to the power stations involves 70 percent by "tied- colliery" arrangement and is supplied via conveyor belts. Hence, the supply-chain process is mine to the power station via conveyor belts. These mines are in the Mpumalanga coalfields where most of ESKOM's coal-fired power stations are situated. With the depletion of coal reserves in the area, the mines have started losing capacity to supply coal to the power stations since the power stations are running at full capacity in order to meet the rising power demands.

Consequently, some of the affected power stations have to receive top-up coal to meet capacity from other mines (new smaller mines) and the deliveries are made by trucks. This top-up coal supply is what constitutes the 30 percent (30mtpa) of which 24mtpa supply is done by road and the 6mtpa by rail. Therefore, the supply chain is mine – power station (by road and rail).The export coal supply chain runs through the 650 kilometres distance between Witbank and Richards bay Coal Terminal by rail (DME 2009: 47).

7.4.1.1 The South Africa coal supply-chain constraints

The constraints for the domestic coal supply chain comprise rail infrastructure, depleting coal reserves in the Mpumalanga coalfields, weather and legislation.

Weather, particularly rain, is a constraint to coal mining and coal stockpiles. The mines (mainly open cast) commonly used in South Africa get flooded during heavy rain. The rain also damages the uncovered coal stockpiles both at the mines and at the customers' place (power station). When the rain water mixes with powder for example the component of coal called "Gypsum", it gets soggy and muddy and it becomes difficult to burn the coal. This was one of the constraints that ESKOM experienced during the power crisis of 2007/2008.

The constraints in the South African export coal supply chain are mainly around rail transportation (lacking capacity, congestion, loading delays at mines). According to (Interviewee 3), erratic rail transportation is blamed on internal problems at TRANSNET that include:

- constrained capital expenditure (expansion of rail network and equipment replacement);
- operations (shortage of rolling stock, locomotives and rail lines, poor planning of train crew);
- copper cable theft;
- non-enforcement of contracts with mines (short-term contracts are used since 2005 lacking commitment);
- maintenance; and

- failure of load-out stations to accommodate longer trains (less wagons means less goods moved).

Congestion is experienced at Ermelo station which is the train assembling point for the coal collected from around the area. The congestion of the rolling stock collected from the mines and the slow pace of making up a train load to be dispatched to the export terminal results in delays. The smaller mines which contribute to export coal use crude methods of loading the rolling stocks (use of spades), resulting in delays. As a result, there are reduced numbers of round train trips from the mines to the export terminal and back to the station.

One respondent commented on the slow and protracted decision-making process on the part of government. He stated that it may take two years to make a decision to build a rail and take another two years to build it. This problem is common in the public sector where the decision-making process is complex due to the hierarchical nature of the organisation.

7.4.2 The depleting coal constraint (Mpumalanga coalfields)

The depleting of coal reserves in the Mpumalanga coalfields poses a major problem to the coal-mining industry in the short, medium and long-term. The current and the short-term problems means that the “tied-colliery” coal production is running low and will only get worse with time.

In the medium-term, the depletion of coal in Mpumalanga will impact on both ESKOM and TRANSNET. ESKOM will continue to buy top-up coal from the spot market at higher volumes (expensive coal) and install rail off-loading facilities. On the other hand, TRANSNET will have to provide additional rail lines to supply the mines. That means extra capital expenditure for building the new rail lines, new locomotives, rolling stock and personnel.

In the long-term, when the coal depletion level deteriorates, coal mines will have to relocate to the Waterberg coalfields in Limpopo Province. That may coincide with the time around which the life of the coal-fired power stations in Mpumalanga will be reaching maturity making them due for decommissioning around 2025. If the coal reserves depletion happens sooner, it will be a dilemma for ESKOM to supply the full capacity of the power station from outside mines (not many available) and meet the increasing energy demands for the country.

All the participants are aware of the threatening situation of coal depletion in Mpumalanga and most of the coal mining companies have or are in the process of securing new coal mines in the Waterberg coalfields. The only problem presently is the lack of infrastructure (rail, road and water) the relocation of South African coal mines to the Waterberg coalfields will be a complex and expensive exercise for all the coal industry role players.

7.4.3 The environmental constraints

One respondent lamented on the environmental degradation in the coal-mining areas of Mpumalanga – the dilapidated ownerless coal mines, continuous burning of coal mine dumps, air and water pollution. However, the respondent reiterated the importance of clean coal technologies as coal is a “dirty” source of power.

All the participants confirmed a continuous liability towards managing the green management issues as required by legislative regulations and through their respective internal organisational structures. The South African major consumers of coal including ESKOM which consumes about 50 percent and the producers of petrochemical products consuming about 18 percent of the national coal production expressed their commitment towards maintaining a successful environmental carbon footprints track.

The power-generating organisations expressed a commitment to having systems in place to control, among others, carbon and particulate emissions and solid waste disposal of polluted water. The respondent provided an example of the World Bank requirements for the loan it secured in 2010 to assist in the completion of the new Medupi power plant which is under construction in Waterberg, Limpopo. Respondent 1 indicated that the World Bank requirements for the loan included:

- the number of accidents to be reduced;
- congestion to be avoided as part of the social benefits of the project;
- attention to be given to the cost of accidents, congestion, road repairs, disruptions to the community and the carbon credits to be realised.

The coal transportation by road was expressed as undesirable for environmental reasons such as road damage, congestion, noise, air pollution from diesel use and other social problems. Some of the reasons advanced for the use of road transportation for coal include:

- quickest way for the coal-fired power plants to receive the required top-up coal in order to meet the country's power demand (good as a contingency plan, but not long-term);
- beneficial to the smaller mining companies that sell their coal on the spot market (receive better prices);
- beneficial to the Black Economic Empowerment companies who are given the transportation contracts.

The road transportation of coal was intensified from the time the power demand growth commenced in 2006/2007. ESKOM has plans to limit coal transportation by road in future, but this will only become possible when TRANSNET increases rail networks and with the appropriate gauge that would allow heavy consignments for example coal to be moved along it.

A number of respondents expressed commitment to functioning within a non-carbon environment through steps taken by individual companies to reduce carbon emissions, water and soil treatment, mine rehabilitation and involvement in research undertaken to develop various processes in the industry. However, the other participants also expressed their organisations/institutions keen interests and participation in the environmental affairs as indicated in the individual interview profiles above.

7.5 CONCLUSION

The chapter provided data presentation, analysis and interpretation for this study. The profile of the participants and the organisations they represent were described. Detailed accounts from the respondents, from which the themes/sub-themes and constraints of this study emerged, were provided. The constraint themes and non-constraint themes were highlighted and elaborated on. A summary of the 13 interviews with the respondents and the current and future status of the South African coal mining industry was provided. .

The next chapter provides the conclusions and recommendations which include the model suggested to alleviate the prevailing constraints in the South African coal-mining industry supply chain.

CHAPTER 8
SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

8.1 INTRODUCTION

This chapter provides the summary, recommendations and conclusions after research into the South African coal-mining industry supply chain. The urge to understand the role of energy in sustainable development and environment triggered interest for pursuance of this study of the supply-chain constraints in the South African coal- mining industry. The aim of the study was not only to explore the supply-chain constraints experienced by the South African coal-mining industry but also to develop a model that would minimise those constraints. In pursuit of this outcome, a study was undertaken on coal as a primary source of energy, its contribution to sustainable development, its impact on the environment and how all of these affect the leading role players in the industry. These considerations formed the basis of the conceptual framework that culminated in the project design that guided the study.

8.2 AIMS AND PRIMARY OBJECTIVES FOR THE STUDY ACHIEVED

The aims and the primary objectives for the study as stipulated in chapter one, to explore the supply chain constraints facing the South African coal mining industry with a view of introducing a model which would alleviate or minimise such constraints were successfully accomplished and a model provided. The model, it is hoped, will enhance integration through improved coordination and collaboration when implemented.

8.2.1 Theoretical/secondary objectives achieved

This study set out to achieve four theoretical/secondary objectives and they were all successfully accomplished as indicated hereunder:

Theoretical objective 1: To review the literature on supply-chain management and how it relates to the coal-mining industry

The literature review on supply chain management and how it relates to the coal supply chain was presented in chapter 2. The chapter discussed the different types of supply chains as well as supply chain collaboration and risks, among other things.

Theoretical objective 2: To critically review the coal-mining industry and its landscape including the historical development and the future outlook of the industry

A critical review of the coal-mining industry and its landscape was conducted in chapter two of the study. This was accomplished though invaluable knowledge on the industry obtained from the industry itself and from some of its major role players.

Theoretical objective 3: To conduct an extensive study of the theory of constraints and how it relates to the coal-mining industry in South Africa

A critical study was undertaken in chapter 5 of the theory of constraints (TOC), its importance and application to the industry, including the coal-mining industry, to improve throughput and profitability. The study covered TOC's origin, its effects on business, the relevance of systems theory, thinking and approach, its application in supply-chain collaboration and plant classification. The other areas covered included capacity management and throughput across the South African coal supply-chain, demand management and the systems applications.

Theoretical objective 4: To explore and establish the impact of the industry on the environment

In chapter 3 the study investigated the environmental impact of coal mining for the provision of primary source of energy required for sustainable development. This included: landscape degradation, water pollution (acid mine drainage), air pollution (dust, particulate and carbon emissions) and soil contamination and erosion.

8.2.2 Empirical objectives achieved

The four empirical objectives set out for the study were accomplished.

Empirical objective 1: To explore the supply chains of the coal-mining industry

South Africa has two types of coal supply chains (domestic and export). Both of these supply chains were explored to provide in-depth understanding of the industry. The domestic coal supply chain is dominated by ESKOM, which consumes about 50 percent of coal produced in the country for power generation, and SASOL, which consumes about 15 percent of the coal produced nationally for the production of synthetic fuels. The export coal supply chain involves the production of export coal from the Mpumalanga coalfields and transporting it to the main coal export terminal at Richards Bay, a distance of 650 kilometres (Section 3.8.2).

Empirical objective 2: To determine the supply-chain constraints or bottlenecks experienced by the coal mines

The empirical study helped identify these constraints. The study also applied the TOC philosophy in developing the model to minimise the constraints. The following five steps provided by the Goldratt Institute (2001-2009: 9) were used:

Step 1: Identify the constraints

Constraints were identified from the empirical study and were highlighted in Chapter 7.

Step 2: Develop a plan for alleviating the identified constraints

A shared vision is recommended for the industry. In this regard, the study recommends the crafting by all stakeholders of the Integrated Strategy on the Development of the Coal mining Industry (ISDCM) in South Africa. Furthermore, the study culminates in a model for minimising the constraints in the coal mining industry (Table 8-1).

Step 3: Focus resources on accomplishing step (2).

The study recommends the establishment of a high-level committee that would be responsible for the implementation of the ISDCM. Such a committee should preferably serve as a sub-committee of the National Planning Commission (RSA 2009b). Improved coal rail freight management system by public and private partnership to enhance collaboration and integration would facilitate the smooth running of the South African rail system. The use of advanced technology for example enterprise resource planning (ERP), Inter-organisational systems (IOS) and others would be applied to enhance operational efficiency. There would be improved integration and collaboration that would enhance the South African coal supply chain optimisation.

Step 4: Reduce the effect of the constraints by expanding capacity or off-loading work.

The study recommends the expansion of capacity by allowing more fresh investment in the mining industry. It also proposes that since the state has been stretched to capacity, the state allows private investment to participate in the ownership of rail, locomotives and rolling stock. The study also recommends a deepening of private public partnerships to be used across the supply chain. Operationally, the use of cutting-edge technology would facilitate the management of constraints and increase throughput and profitability.

Furthermore, the study proposes replacing the existing old rail network and building new rail lines with the standard gauge that allows carriages to be moved via rail and easily fitted on trucks for road transportation.

Step 5: Go back to step (1), identify the new constraints and repeat the process of alleviation again.

Usually when identified constraints are alleviated new constraints emerge at another point and the five step processes are repeated (Goldratt Institute 2001-2009:9).

Empirical objective 3: To determine environmental issues germane to the industry

As indicated in the above paragraph, environmental issues came out as some of the leading constraints in the South African coal mining industry (Section 7.3).

Empirical objective 4: To develop a model that would minimise the supply-chain constraints in the coal mining industry

This study has established that all the major constraints in the South African coal mining industry are interlinked and there is a low level of coordination and collaboration in the industry. Transport logistics, especially rail transportation, poses great challenges to the industry and to the role players due to the lack of a balanced integration. The constraint can be resolved by sharing the rail infrastructure, equipment and facilities between public (Government through TRANSNET) and private sector (mining industry) through a public and private partnership (PPP) business model. This study culminated in a PPP business model that would streamline the South African coal mining industry supply chain. The model and the operational mechanisms are stipulated in the paragraphs that follow.

8.3 MINIMISING CONSTRAINTS IN THE SOUTH AFRICAN COAL-MINING INDUSTRY SUPPLY CHAIN

After analysing the research data, eight major themes emerged along with other sub-themes some of which characterised the constraints experienced in the South African coal-mining industry supply chain. The following diagram represents the model for minimising supply-chain constraints in the South African coal-mining industry:

Table 8-1 Supply-Chain Constraints Minimisation Model for the South African Coal-Mining Industry

INDUSTRY CONSTRAINTS				
Source		Distribution/ Transport Mode	Customers	
Coal Mine	Stockpile	Conveyor	-Power Station -SASOL	
		Road	-Power Station -SASOL -Industry	
		Rail	-Power Station -Traders -Export(RBCT)	
• Skills shortage within the coal mining industry • Little or no new entrants to coal mining		• Aged and inadequate transport and rail capacity (old gauge) and infrastructure • Ownership of the transport and rail infrastructure wholly in the hands of state		
CROSS-ENTERPRISE CONSTRAINTS				
• Lack of common and shared vision among enterprises within the coal mining industry • Lack of flexibility in the policy and legislative domain affecting the mining industry • Skills shortage across the entire supply chain within the coal mining industry				
INTERVENTIONS TO MINIMISE CONSTRAINTS				
• Effective skills development strategy for the industry • Shortening the mining licensing application and granting process		• New investment in the transport and rail infrastructure • Co-ownership of transport and rail infrastructure by private investors		

Integrated strategy on the development of the coal mining (ISDCM)

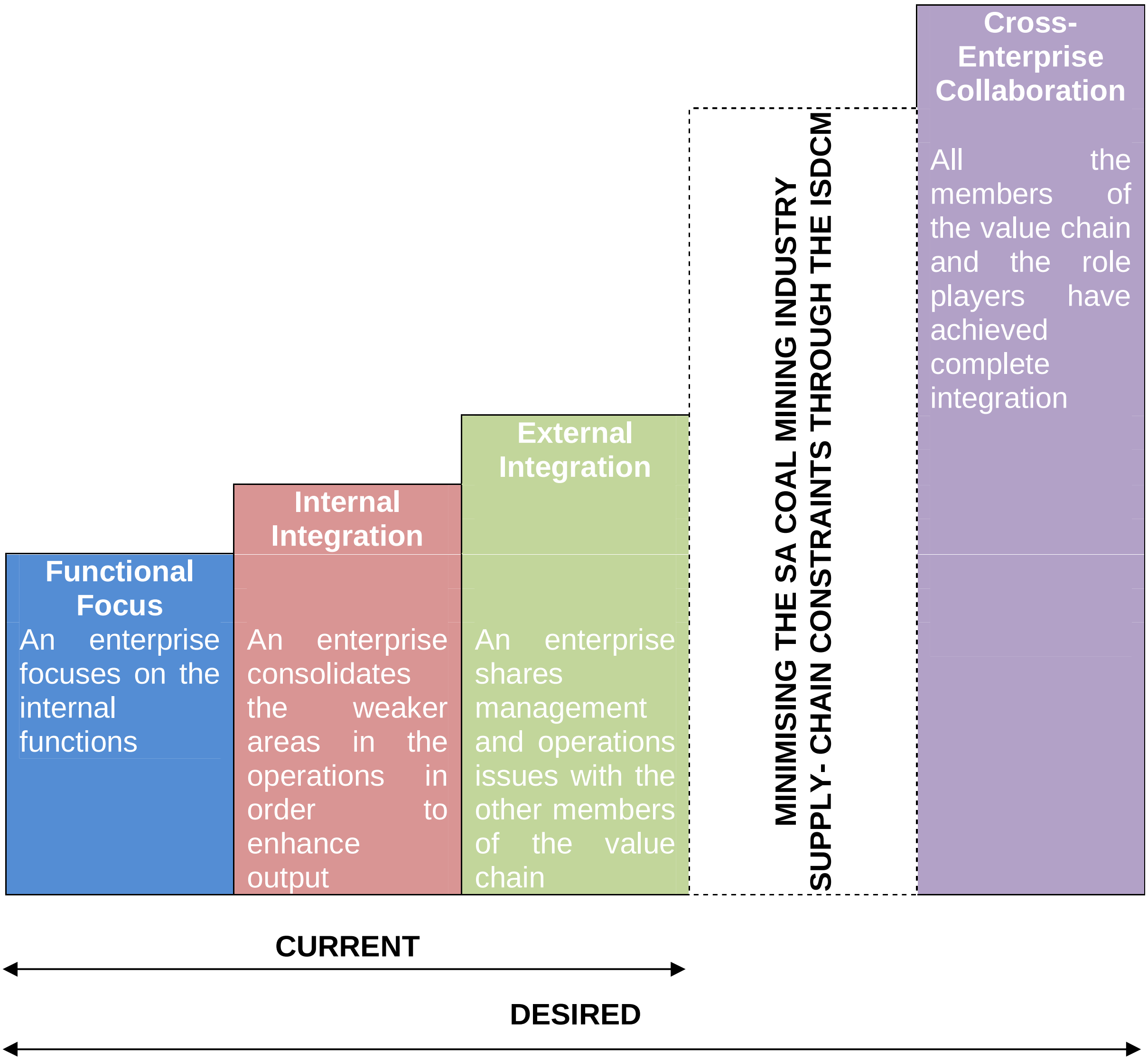
Source: Own model

The above model provides a strategy for minimising constraints in the South African coal-mining industry. The top level of the model indicates the processes of mining, coal stockpiling and coal distribution to the end users. The transportation modes used to deliver coal to various customers are indicated (conveyor, road and rail).

The second level highlights the industry constraints while the third level indicates the cross-enterprise constraints. The fourth level indicates the intervention processes to minimise the constraints.

The following figure indicates the direction the South African coal mining industry would need to take in order to realise the cross-enterprise collaboration.

Figure 8-1 The South African Coal Supply-Chain Challenges to Optimisation



Source: Own model

The above figure shows the current status of the South African coal mining industry and the desired aim to reach the cross-enterprise integration. Under the prevailing situation the industry has stagnated at the functional focus, internal integration and external integration. However, when the integrated strategy on the development of the coal mining (ISDCM) gets implemented, the industry would achieve the desired level of cross-enterprise integration.

The following section highlights the major constraints and discusses ways of minimising them:

8.3.1 Policy and legislative environment – minimising the constraint

With the implementation of the proposed coal transportation model the other constraints which are inter-linked will also be alleviated. The policies adversely affecting the coal industry supply chain would be renegotiated and resolved favourably. Among such policies would be the legislation (Mining Act of 2002) which is presently perceived as cumbersome by the industry as the process is lengthy and discourages prospective investors. This would change the current and future status of South African coal mining industry as there would be new entrants even before the industry relocates to the Waterberg coalfields.

8.3.2 Lack of shared vision – minimising the constraint

The dilemma of the South African coal mining industry supply chain was established to a greater extent to be due to poor communication among the industry role players. This culminates in mistrust, diminished coordination and collaboration. There is a need for an integrated strategy on coal mining for South Africa. This kind of integration advocated by this study would lead to other avenues for collaboration, instil confidence and enhance transparency among the role players in the coal supply chain. However, there has to be a reasonable and an agreeable level of coordination and collaboration among the parties involved (government and private sector) in order to harmonise the processes of service delivery.

Presently, the South African private coal-mining industry and the public sector which controls the rail freight transportation and the policy decisions for the industry lacks enough coordination and collaboration to facilitate a smooth running coal supply chain.

8.3.3 Damage to roads – minimising the constraint

Approximately 50 percent of the coal mined in South Africa is consumed by power stations as fodder for power generation. The coal transportation to the power stations is 70 percent by conveyor, 24 percent by road and 6 percent by rail. The constraints in the domestic coal supply chain are featured more in the transportation to the power stations. The power stations were built over the Mpumalanga coalfields for the ease of transportation costs. All the coal-fired power stations are connected to an adjacent coal mine in order to supply coal via conveyor belts. Most of the mines were funded by ESKOM or signed cost-plus-contract arrangement called “tied-colliery”.

The coal mine supposed to supply Majuba power station failed due to geological complications (mine too deep and gaseous) and Tutuka power station receives approximately 50 percent from its designated mine. As a result, Majuba has to receive coal from other mines and the top-up supplies for Tutuka and other power stations, which have below capacity coal supplies from their designated mines due to coal resources depletion. The coal supply to Majuba and the top-up for the other power stations comprise 30 percent of the total coal consumption for power generation.

Currently, the bulk of freight haulage in South Africa is by road. It is only the bulky products for example coal, iron ore, cement and agricultural produce that are moved by rail. Approximately 83 percent of freight is transported by road and the bulk of it comprises manufactured goods (CSIR 2010:20). Using rail/road intermodal system would optimise the utilisation of the transportation modes and spare the road damages from the heavy trucks. This would result in increased use of smaller and lighter trucks and increase road life longevity.

8.3.4 Rail and infrastructure – minimising the constraint

In the export coal supply chain, the constraints are mainly attributed to infrastructure capacity and operational problems at TRANSNET, which include shortage of locomotives, shortage of rolling stock, skills shortage, theft of rail and copper wire, among others. The South African coal export has dropped in the last five years, while the handling capacity at RBCT has increased from 72Mtpa in 2008 to 91Mtpa in 2010. The 2009 export was 61.1Mt. The other constraint is attributed to reduced capacity and fewer train loads due to slow loading process at the smaller mines for lack of appropriate rolling stock loading facilities.

According to Prevost (2010:17), India will start importing 25Mtpa from South Africa effective 2012 as part of its 110Mtpa increased coal imports to meet its increased energy demand. This proposal has motivated TRANSNET belatedly to launch the Quantum Leap Project to develop towards 81Mtpa capacity and beyond.

The current rail infrastructure would be improved by changing it to a wider gauge to accommodate heavier carriages and new lines would be added to feed all the power stations and boost export coal to the export terminals including RBCT. An intermodal transport system rail/road would be introduced to streamline goods haulage with rail used for longer distances. The coal haulage by road would be minimised to reduce damage to the environment and reduce road repair costs.

Domestic rail transportation is the key issue in the coal supply chain so it is paramount for the government through TRANSNET to share the coal transportation risks with private enterprise and to promote the relationship and flexibility between the two sectors. With the speedy diminution of coal reserves in the Mpumalanga coalfields where most of the coal-fired power plants are situated, the supply of the top-up coal for those power stations to meet the required generating capacity will require a dependable, reliable and cost-effective mode of transport which can only be the rail system. This is over and above the rail to meet the rising export coal capacity, which requires effective, rational planning by the two parties to always maintain capacity parity between the rail haulage and export terminal (RBCT).

This study recommends the implementation of coal rail/road inter-modal infrastructural system and an infrastructure regulatory authority. An infrastructure authority is crucial in recommending the desired infrastructure, setting tariffs, arbitrating industry disputes and enhancing logistics professionalism. Its role will be to steer the country towards a rail/road intermodal infrastructure to streamline the freight haulage.

The rail system would have to be modernised by replacing the existing old rail and building new rail lines with the standard gauge which allows carriages to be moved via rail and easily fitted on trucks for road transportation. The country would be required to follow or benchmark the best system that would function well in South Africa from the existing models in the world. The most successful models are public and private partnership (PPPs) and this is what this study recommends. Such a model would enhance the government transportation service delivery agenda and would be a framework for sustainable development.

8.3.5 Skills shortage – minimising the constraint

The need for more power stations and new mines calls for more skills in the technical areas. A very important element of the Integrated Strategy on the Development of Coal Mining (ISDCM) would have to be the skills development plan for the industry. The skills shortage is found across the supply chain, in other words from the mines through the transport and distribution system and to the users. Wilhelm (2009:6) estimates that building 40 power stations would require 600 engineers and 2 500 artisans.

8.3.6 Lack of fresh investors – minimising the constraint

Fresh investment in the industry seems to be hamstrung by the stringent and cumbersome requirements from the policy and legislative environment. Once these requirements are relaxed and the government communicates its position on the proposed nationalisation of mines, the economy should see fresh investors in the coal-mining industry.

8.3.7 Environmental issues – minimising the constraint

The impact of coal mining on the environment would remain, but stringent remedial measures would be introduced. Such measures would include rehabilitation of disused coal mines, soil and water pollution control, treatment of acid mine drainage (AMD) and a reduction of air pollution (dust, particulates and carbon emissions). The carbon emissions (emission of greenhouse gases) to the atmosphere to be controlled through reduction mechanisms as recommended by United Nations Framework Convention on Climate Changes (UNFCCC) treaties – Kyoto Protocol, 1997 and Copenhagen accord, 2009. Those mechanisms involve the use of clean coal technologies like flue gas desulphurisation for power generation, carbon capture/storage and carbon trading. Hence, the environmental management will remain work-in-process.

8.3.8 Ownership of the rail (TFR/TRANSNET) – minimising the constraint

With the ownership of the crucial rail infrastructure under the State management and control, it will be difficult to optimise the coal supply chain. The state needs to allow for more private ownership of the locomotives and trains. A public and private partnership (PPP) in the running of the rail would be the most desirable solution to the prevailing situation as is evident in some of the developed countries. The best PPP practice in this case can be benchmarked from countries with the best practice. The principle that applies to the toll road system can also be applied in the case of rail.

The following figure depicts the model of ownership within the coal mining industry in South Africa:

Table 8-2 Current Model of Ownership within the South African Coal-Mining Industry Supply Chain – (Assuming 33.33 percent share for each coal supply chain stage)

STAGES	OWNERSHIP	% CONTRIBUTION (est.)
1.MINES (5 leading) -Anglo Coal -BHP Billiton -SASOL -Exxaro -Xstrata	Private (all)	Private (33.33)
2.INFRASTRUCTURE -Conveyor -Rail -Road -Port	Private TRANSNET (Public) GOV (Public) Privately owned on TRANSNET property	Public (33.33)
3.CUSTOMERS -ESKOM -SASOL -Industry -Export	GOV (Public) Private Private Private	Public (16.66) Private (16.66)
Total Private		50.0
Total Public		50.0

Source: own model

The above figure shows that the current South African coal mining industry supply chain ownership assumed to be private/public in the ratio of 1:1. This is done by assuming the three stages of the present supply chain: mine, transportation and customer in equal proportion for the purpose of comparison. In that context the supply chain ownership appears balanced and could allow integration that would enhance coordination and collaboration, but would require unbiased management. This current coal supply chain ownership model requires adjustment in the second stage of the value chain (transportation) which is crucial for the two parties for balancing deliverables with minimal biases.

The proposed future coal supply chain design that follows suggests private participation in the ownership of the coal rail transportation as indicated by the table and the mechanics of involvement (Public and Private Partnership model).

Table 8-3 Proposed Ownership Model of the South African Coal-Mining Industry Supply Chain – (Assuming 33.33 percent share for each of the supply chain stages)

STAGES	OWNERSHIP	% CONTRIBUTION (est.)
1.MINES (5 leading) -Anglo Coal -BHP Billiton -SASOL -Exxaro -Xstrata	Private (all)	Private (33.33)
2.TRANSPORTATION -Conveyor -Rail -Road -Port	Private TRANSNET (Public) GOV (Public) GOV (Public)	Private (15.00) Public (18.33)
3.CUSOMERS -ESKOM -SASOL -Industry -Export	Public Private Private Private	Public (16.66) Private (16.66)
Total Private		65.00
Total Public		35.00

Source: own model

The proposed future design of the South African coal mining industry supply chain increases the role played by the private sector with aims of increased commitment, risk sharing and logistics reasons. The above design is transformed in the model that follows below into a PPP model which works well in some of the developed countries. In this design and in the model that follows, the supply chain ownership theoretically becomes private sector (65 percent) and public sector (35 percent). It is theoretical because those are assumed rates. However, the importance for this arrangement would provide the coal mining industry with the opportunity to participate in the coal rail transportation decision-making process.

Hence, this PPP strategy would lead to the introduction of an inter-modal system (rail/road) that would not only benefit the coal supply chain, but also tap into the lucrative freight from the manufacturing sector which is dominated by the road transport sector. The long distance haulage of goods by road is more expensive compared to the use of rail. That is why rail/road intermodal systems are prevalent in most of the developed countries.

Over and above the 35 percent assumed public sector ownership of the coal supply chain in this present design, the government controls other infrastructures for example energy, water and telecommunication that are crucial for supply-chain operations. The public sector is also responsible for policy and legislation framework which binds all the industries. These crucial contributions by the public sector are not easily quantifiable, but they are the framework for sustainable socio-economic development.

Indeed, the operation of the RBCT is testimony to a successful PPP model as the terminal operates under the South African Ports Authority's jurisdictions under TRANSNET. Hence, private participation in the rail infrastructure and operations ownership would have every probability of success like RBCT.

At the implementation stage it is suggested that the private sector would commence ownership of the coal freight locomotives and rolling stock by undertaking liability of the capital expenditure for the fleet through transfer from TRANSNET order book with the financiers. They would also sign a long-term service/maintenance agreement with TRANSNET which would continue to own the fixed facilities. This transaction would forge closer relationships between the public/private sectors and strengthen operational integration.

The PPP business model is proposed whereby the private enterprises partners with the government in the ownership of the rail infrastructure and operations. The figure below shows a proposed public and private partnership (PPP) model of the South African coal rail transportation comprising TRANSNET and private enterprise/s as partners:

Table 8-4 The Proposed Key Performance Areas for TRANSNET & Private Partner (PPP) Rail Transportation Model

Ownership	Constraints	Present (2010)	Future	Achievement
TRANSNET & Private Partner/s	-Rail lines (age and gauge) -inadequate rail lines	Old gauge 1065mm	New gauge 1435mm	Improvement New rail lines to be built
	Capacity	60Mtpa	RBCT 91 Mtpa level	Throughput increase
	Locomotives	Inadequate	As required	Efficiency
	Rolling stock	Inadequate	As demanded	Efficiency
	Workers' skills	Shortage	Consistent training	Efficiency
	Communication (with role players)	Poor	Improved systems based on 'Integrated Strategy'	New PPP management, improved performance and integration
	No long-term contracts with coal mines	Short-term contracts	Long-term contracts	Operations optimisation in coal haulage
	Theft (rail & copper wire)	Prevalent	Outsource	Stop

Source: Own model

The above figure shows TRANSNET with a private partner in a PPP model. The second row lists the major constraints experienced by TRANSNET. The third row provides the constraints status presently while the fourth row indicates what would happen in future when the PPP model is implemented. The modalities of implementation are explained under the proposed design above. The last row indicates the achievements after implementation of this model. The Theory of Constraints states that when identified constraints are rectified, other bottlenecks move to another part (Geri & Ahituv 2008:34).

8.4 THE NEED FOR A SYSTEMS APPROACH, AN INTEGRATED STRATEGY AND COLLABORATION WITHIN THE COAL-MINING INDUSTRY IN SOUTH AFRICA

The South African coal-mining supply chain needs to be process-centric in that it should narrow the coordination gap between the coal mines and the rail infrastructure to improve customer service and profitability (throughput). The other stage of the proposed coal supply chain (customers/consumers) would be further streamlined by the improved rail/mine collaboration, endorsing the “client is King” concept (Waller 2003:758).

In order to streamline the strategy and regulatory environment, the Department of Transport intends to, among other things, develop an integrated service delivery model for transport which would involve all transport delivery agencies within the government and outside government through the PPPs. The department would also identify the capacity gaps through the transport value chain and provide strategic and project management support. In view of this, the rail transport policy would be developed with the aim of moving more cargo from the road transport to rail transport. Other logistics issues to be addressed would include capital investment backlogs, security, rolling stock, aging infrastructure, inefficient operations and skills shortage (DoT 2010: 2-10).

This proposal by the Department of Transport, which came out after the findings of this study, has shown the importance of changing the current rail freight model with a public and private partnership model which has capacity to improve the present state of transportation and grow the current rail freight. The rail freight and rail/road intermodal transport system is what the developed countries use for heavy and long distance haulage. It is therefore hoped that this study will be invaluable to DoT in developing a “Service Delivery Model” and the author would welcome the opportunity to make such a contribution.

Collaboration between the relevant government departments: Mineral Resources, Energy, Transport, Public Enterprises, Water and Environmental Affairs, the State corporations: ESKOM and TRANSNET with the role players in the coal-mining industry would go a long way to minimise constraints, to enhance productivity in the mining industry and to meet present and future energy demand with ease. Such collaboration would lay the infrastructure for sustainable development and become a catalyst for service delivery.

8.5 PROPOSED INSTITUTIONAL ARRANGEMENTS FOR THE IMPLEMENTATION OF ISDCM

The integrated strategy on the development of the coal-mining (ISDCM) coordination committee comprising all stakeholders in the coal-mining industry would need to be established in order to formulate and implement the ISDCM. The coordination committee work would feed directly into the National Planning Commission. The National Planning Commission is best suited to deal with this strategy since it focuses on 'long term cross-cutting issues such as food, energy and water security' (RSA 2009b: 4). While the ISDCM deals with the coal-mining industry, it ultimately deals with energy issues, which are so critical for the nation. Its membership would also include experts in energy, engineering, researchers, coal logistics, mining, rail/road/water infrastructure, environment, commodity traders, economics, planning and finance among others.

The establishment of the ISDCM coordination committee would be a milestone in streamlining of some of the most critical national development issues. Government departments would speed up policy interpretation to open up the team's planning and processes. The issues on the PPPs and the IPPs should be clarified to pave the way for future development. The transparency and integrity of the committee are paramount for the success of this project.

8.6 LIMITATIONS OF THE STUDY

This study, being qualitative, had a limitation on the number of participants. A total of 13 participants from the coal industry and the role players were interviewed. These were all professionals in the industry and included three chief executives. Recruiting such high calibre professionals was time-consuming in accessing them and their institutions, as explained in the methodology chapter. However, the response by 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 use in most domains in society. The institutions in the industry are not easily accessible without good 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 complete this project.

8.7 RECOMMENDATIONS

Jiang, Zhou and Meng (2007:6) observed that constraints of the coal supply chain manifest themselves in the following ways:

- most companies have not implemented the supply chain concept theories;
- most coal companies are profit-driven and overlook the cooperation and information-sharing with other members of the value chain;
- in many cases the employees are not well trained in supply-chain management;
- constraints are usually experienced in transportation and resources.

To an extent this study has corroborated the observation made above in that:

- The coal mining industry needs to move from internal focus to cross-enterprise collaboration.

- Such cross-enterprise collaboration will enable industry players to look beyond the profit focus and to start seeing the value of cooperation and information-sharing with other members of the supply chain. Indeed, this is one of the constraints that emerged from the study. ISDCM will hopefully facilitate communication among all the role players in the coal-mining industry.
- Skills shortage has emerged as one of the major constraints for the industry and will be more acute with the infrastructural developments envisaged. The skills development plan will inform the industry of the extent, areas, and ways to address skills deficiencies in the industry.
- Rail and transportation have also emerged as a serious constraint.

Thus the following recommendations are made:

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 focus of the ISDCM should be on the constraints raised in the study. In other words the critical elements of the strategy should be:

- a policy and 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 TFR/TRANSNET;and
- managing the environment.

As indicated earlier, the ISDCM coordination committee first needs to be set up by the Ministerial Planning Committee of the National Planning Commission. Its mandate would include developing and implementing the ISDCM.

Future Research recommendations: In support of the work of the proposed ISDCM coordinating committee a number of areas need to be looked into more closely to make more informed decisions. First, further research will need to be undertaken to determine the impact of the new coal mining and power station developments on the skills requirements in the industry. Secondly, a study needs to be conducted on the perceptions and expectations of the potential investors in this industry. Thirdly, a feasibility study needs to be done on the diversifying of the ownership and management of the rail, locomotives, and rolling stock to private investors. Fourthly, research needs to be undertaken into the potential effectiveness of the PPPs in this industry.

8.8 SYNOPSIS

The aims and objectives of the study both theoretical and empirical were realised and a model developed to minimise some of the constraints identified from the South African coal-mining industry. The need for a systems approach, an integrated strategy and collaboration within the coal-mining industry in South Africa was established. The study also proposed institutional arrangements for the implementation of an integrated strategy on the development of coal mining (ISDCM). In support of an ISDCM research was recommended into the fields of coal-mining and power stations development, perceptions and expectations of potential investors in the industry, diversifying rail and infrastructure to private ownership and into the effectiveness of the PPPs in the coal mining and affiliated industries.

BIBLIOGRAPHY

ABBOTT, K., APOSTOLIK, R., GOODMAN, G., JENNER, M., LABHART, G., MARAGOS, S., MAY, M., SUNDERMAN, A. D., PARKE, J., STEIN, J., WENGLER, J. & WENT, P. 2009. *Foundations of Energy Risk Management: An overview of the energy sector and its physical and financial markets*. Global Association of Risk Professionals (GARP). Hoboken, NJ: John Wiley.

Anglo Coal. 2007. *Annual Report*.

Anglo Coal. 2008. *Annual Report*.

ANKLESARIA, J. 2008. *Supply-Chain Cost Management: The Aim and Drive Process for Achieving Extraordinary Results* New York: American Management Association (AMACOM).

ANNANDALE, J. G., BELETSE, Y. G., STIRZAKER, R. J., BRISTOW, K. L. & AKEN, M. E. 2009. *Is irrigation with coal-mine water sustainable?* Abstract of International Mine Water Conference held in Pretoria on 19-23 October 2009. Pretoria, pp. 337-342.

ASH, P. 2010. Old equipment, tough competition, restive workers and metal thieves challenge South African railways. *The Star,* 20 June, p. 6.

ASHTON, G. ESKOM is an enemy of progress. *The Star,* 29 January 2010, p.15.

ASIF, M. & MUNEER, T. 2007. Renewable and Sustainable Energy Reviews. Energy Supply, its Demand and Security Issues for Developing and Emerging Economies. *Science Digest.* Vol. 11 pp. 1388-1414. Elsevier.

BARBOUR, R. 2008. *Introducing Qualitative Research: A Student Guide to the Craft of doing Qualitative Research*. London: Sage.

BARNES, D. 2008. *Operations Management: An International Perspective*. London: Thomson Learning.

BARR, R. 2009a. Global Proven Oil Reserves Take Plunge: BP Oil Company Annual Statistical Review. *The Star, Business Report (International).* 11 June p. 8.

BARR, R. 2009b. Consumption of Coal Rises Despite Escalating Prices. (BP Oil Company Annual Statistical Review). *The Star, (Business Report International).* 11 June, p. 8.

BAUR, A., BYER, J., HANSEN, G., HARVEY, E., HEMLER, D., MASON, P. J., TENNEY, N. & BRIGHT, M. Coal in the Heart of Appalachian Life. Fairmont State University, Fairmont, West Virginia. [Online.] Available at: <http://www.serc.carleton.edu/sencer/coal appalachian/index.html>. Accessed: 2 June 2008.

BELL, F. G., BULLOCK, S. E. T., HALBICH, T. F. J. & LINDSAY, P. 2001. Environmental impacts associated with an abandoned mine in the Witbank coalfield, South Africa. *International Journal of Coal Geology* 45, pp.195-216.

BISCHOFF, F. 2009. Coal haulage. *IMIESA*, October, pp.100-101.

BIYASE, L. & SPECKMAN, A. 2010. Shabangu to cut wait for mining licenses. *The Star Newspaper, Business Report*, 3 February, p.17.

BLACKSTONE, J. H. 2001. Theory of Constraints (A Status Report*). International Journal of Production Research*. Vol. 39, No. 6, pp.1053-1080.

BLOY, S. 2005. Energy, coal mining and rehabilitation of the environment. *Discourse,* Vol.33.1, pp.35-39.

BOLSTORFF, P. & ROSENBAUM, R. 2003. *Supply Chain Excellence: A Handbook of Dramatic Improvement Using SCOR Model.* New York: American Management Association (AMACOM).

BOWDEN, G. A. 2005. Preparing a qualitative research-based dissertation: Lessons learned. *The Qualitative Report* Volume 10 Number 2 June, pp. 208-222. [Online.] Available at: <http://www.nova.edu/ssss/QR/QR10-2/bowen.pdf> Accessed: 12 January 2009.

BOWERSOX, D. J. CLOSS, D. J. & COOPER, R. B. 2007. 2nd ed. *Supply Chain Logistics Management.* New York: McGraw-Hill Education (Asia).

BOYSON, S., HARRINGTON, L. H. & CORSI, T. M. 2004*. In Real Time: Managing the Supply Chain.* Westport: Praeger.

BOYER, K. K., FROHLICH, M. T. & HULT, G. T. M. 2005. *Extending the Supply Chain.* New York: American Management Association (AMACOM).

BOZARTH, C. C. & HANDFIELD, R. B. 2006. *Introduction to Operations and Supply Chain Management.* Upper Saddle River (NJ): Pearson Prentice Hall.

BREDELL, R. & WATERS, J. 2009. Integrated supply chain management*. Journal of Transport and Supply Chain Management*, pp.1-15.

BROWN, J. 2009a. Delayed Projects. *The Star, Business Report*. 8 June, p.16.

BROWN, J. 2009b. Exxaro Group Looks at Joining Sasol and IDC as Investor in Coal Mine to be set up in Limpopo. *The Star, Business Report.* 2 July p. 3.

CALIFORNIA ENERGY COMMISSION. 2010. [Online]. Clean Alternative Fuels: Fischer-Tropsch. Available at: <www.energy.ca.gov/efrs/synthetic diesel.html > Accessed: 12 August 2010.

CASSEDY, E. S. & GROSSMAN, P. Z. 2000. *Introduction to Energy: Resources.* Cambridge: Cambridge University Press.

CCM Global Overview. 2008. *Role of coal in South Africa*, pp.195-203.

CHADWICK, J. 1994. World Coal. *Mining Magazine*. September Issue. London. Mining Publication.

CHAMBER OF MINES OF SOUTH AFRICA. 2008. Annual Report.

CHAMBER OF MINES OF SOUTH AFRICA. 2009. Annual Report.

Civil Engineering. 2008. Richards Bay Coal Terminal being expanded. *Civil Engineering*, p.38.

CLAASENS, S. 2003. Soil Microbial Community Function and Structure as Assessment Criteria for Rehabilitation of Coal Discard Sites in South Africa. MA (Env) Dissertation: North-West University (Potchefstroom).

CHOPRA, S. & MEINDL, P. 2nd ed. *Supply Chain Management*. Upper Saddle River, N.J : Pearsons Education.

CHRISTOPHER, M. & PECK, H. 2004. 2nded. *Marketing Logistics.* Oxford: Butterworth-Heinemann.

Coal International. 2007. International energy outlook. [Online]. Available at: <www.eia.doe.gov/oiaf/ieo/coal.html>. Accessed: October, 2008.

COETZER, R. L. J. & KRUGER, M. J. 2004. Robustness studies on coal gasification process variables. *SASOL Technology*, Volume 20 (2), pp.89-108 [Online.] Available at: <www.orssa.org.za>.Accessed: (DATE MISSING).

COHEN, S. & ROUSSEL, J. 2005. *Strategic Supply Chain Management*. New York: McGraw-Hill.

COOPER, D. R. & SCHINDLER, P. S. 2008. 10th ed. *Business Research Methods*. New York: McGraw-Hill.

COPANS, G. 2008*.* Tracking Acid Mine Drainage. *Mining Weekly,* Vol. 14 No. 16, 2-8 May, p. 23.

CORBIN, J. & STRAUSS, A. 2008. 3rd ed. *Basics of Qualitative Research*. Thousand Oaks (CA): Sage.

Council for Scientific and Industrial Research (CSIR). 2010. 6th Annual state of logistics survey for South Africa. *CSIR, IMPERIAL Logistics and Stellenbosch University*.

Council of Supply Chain Management Professionals (CSCMP). 2000-2010. Supply Chain/Logistics Definitions. [Online]. Available at: <file://C:\Documents and Settings\Ken\Loca Settings\Temp\Rar$EX02.562\Supply Chain...>.Accessed: (DATE MISSING)

CRAWFORD, O. 1993. Surface molecular anchoring in microfined liquid crystals near the nematic-smectic-A transition. [Online]. Available at: <http://link.aps.org/doi/10.1103/PhysRevE.48.1998>. Accessed : 23 April 1993.

CROTTY, A. Coal procurement constrains Eskom’s output. *The Star*, pp.3. SA Media – The University of Free State. Ref No: 788.

Datamonitor. 2007. *Global Coal and Consumable Fuels.* March, New York.

DATTA, B. K., MUKHERJEE, S. SIMON, T. & BATRA, .2008. Supply chain risk management: Discussion, pp.158-167.

DAVIS, M. D. & HEINEKE, J. 2005. *Operations Management*. 5th ed. New York: McGraw-Hill.

DAVIS, M. M., AQUILANO, N. J. & CHASE, R. B. 2003. *Operations Management*. 4th ed. New York: McGraw-Hill/ Irwin.

DAVIS, M. M., AQUILANO, N. J. & CHASE, R. B. 2003. *Fundamentals Operations Management.* New York: McGraw-Hill/Irwin.

Department of Environmental Affairs and Tourism (DEAT) see REPUBLIC of SOUTH AFRICA. Department of Environmental Affairs and Tourism.

Department of Minerals and Energy (DME) see REPUBLIC of SOUTH AFRICA. Department of Minerals and Energy.

Department of Mineral Resources (DMR) see REPUBLIC of SOUTH AFRICA Department of Mineral Resources

DEVERS, K. J. & FRANKEL, M. 2000. The study design in qualitative research-2: Sampling and Data Collection Strategies. *Education for Health*, Vol. 13, No.2, pp.263-271.

DEVLIN, A. S. 2006. *Research Methods (Planning, Conducting and Presenting Research).* Belmont (CA): Thomas Wadsworth (Thomas Learning).

De WET, T. J. & van HEERDEN, J. H. 2003. The dividends from a revenue neutral tax on coal in South Africa. *SAJEMS* NS6. NO.3.

DHARMAPPA, K., WINGROVE, M., SIVAKUMAR, M. & SINGH, R. 2000. Water and stormwater minimisation in a coal mine. *Journal of Cleaner Production*, 8 (2000), pp.23-34.

Dispatch. 1998. Eastern Cape. November.

DONALDSON, S. I., CHRISTIE, C. A. & MARK, M. M. 2009. *What Counts as Evidence in APPLIED RESEARCH and EVALUATION Practice.* Thousand Oaks (CA): Sage.

DRY, M. 2010. Fischer-Tropsch Technology. [online] Available at: <http://www.elsevier.com/find/bookdescription.cws_h > Accessed: 30 September 2010.

EBERHARD, A. 2009. Ten ways to provide the country with more and cleaner power. *Business Day,* 21 May, p.16.

EHIGIE, B. O. & EHIGIE, R. I. 2005. Applying qualitative methods in organisations: A note for industrial/organisational psychologists. *The Qualitative Report* Volume 10 Number 3 September, pp.621-638. [Online.] Available at: http://www.nova.edu/ssss/QR/QR10-3/ehigie.pdf. Accessed: 13 September 2010.

EKAWAN, R. & DUCHENE, M. 2006. The Evolution of Hard Coal Trade on the Atlantic Market. *Energy Policy 34*. Pp.1487-1498. Elsevier.

ERGO Energy. 2010. Underground coal gasification. [Online]. Available at: <http://www.ergoexergy.com/index.htm> Accessed: 30 September 2010.

ERIKSSON, P. & KOVALAINEN, A. 2008. *Qualitative Methods in Business Research*. London: Sage.

ESKOM. 2007. *Annual Report.*

ESKOM. 2008. *Annual Report.*

ESKOM 2009. Annual Report.

ESKOM, PIMARY ENERGY DIVISION. 2008 Report.

ESKOM, PRIMARY ENERGY DIVISION. 2009. Report.

EVANS, J. R. & COLLIER, D. A. 2007*. Operations Management* (*An Integrated Goods and Services Approach)* Mason, OH: Thomson South-Western.

EXXARO. 2007. *Annual Report.*

FAUCONNIER, C. J. & KERSTEN, F. 1982. Increased Underground Extraction of Coal*.* The South African Institute of Mining and Metallurgy. Monograph Series No. 4. South Africa*. The Institute of Mining and Metallurgy.*

FAUCONNIER, C. 2005. Waterberg – The future of South African coal mining industry? *Mining Indaba,* 8 February, pp.1-9.

FABRICIUS, P. 2009. 2010 World Cup 's unwanted legacy*. The Star.* 26 November, p.11.

FAYAZBAKHSH, K., SEPEHRI, M. & RAZZAZI. 2009. Supply chain coordination with flow networks. *South.African Journal of Business. Management* 40(2).

FINCH, B. J. 2008. 3rd ed. *Operations Now*: *Supply Chain Profitability and Performance* .New York: Mcgraw-Hill/ Irwin.

FISHER, M. L. 2000. Supply chain inventory management and the value of shared facilities: Enonometric analysis of inventory turnover. [Online]. Available at: <mansci.journal.informs.org/cgi/content/abstract/46/8/1032. Accessed: 8 August 2000.

FLICK, U. 2003. 2nd ed. *An Introduction to Qualitative Research*. London: SAGE.

FLOOK, S. D. & LEEMING, J. J. 2006. The Potential to Increase Production and Development in the Russian Underground Coal Industry. *Coal International*. May/June I.

FOLCONER, K. W. 1989. A Review of Cost Comparison of the Three Main Methods of Underground Coal Mining in South Africa. MSc (Eng) Dissertation. *University of Witwatersrand*. Mining Engineering. Project No. 318094. National Research Foundation (NRF).

FOSTER, R. J. 1982. *Coal for the steel industry*. American society for metals, iron-making and steel-making.

Foundation (NRF). 2007. Bulk Handling. *Coal International*, May/June.

FOURIE, Y. 2005. Impediment to the structural development of the South African maritime supply chains. *Journal of Transport and Supply Chain Management,* pp.46-64.

FROHNE, P. T. 2008. *Quantitative Measurements of Logistics.* New York: McGraw-Hill.

FURTER, L. 2005. Logistics systems. *TWA.* March/April, p.13.

GATTORNA, J. L. 5th ed. 2003. *Gower Handbook of Supply Chain Management (Operating Strategy, Agile Supply Chains)*. Aldershot, England: Gower Publishing.

GERI, N. & AHITUV, N. A Theory of Constraints approach to inter-organisational systems implementation. 2008. *Information Systems E-Business Management* 6: 341-360. DOI 10.1007/s10257-007-0075-8. Springer-Verlag 2007. Access date: 29/11/2007.

GILLILAND, J. 1982. Planning and Establishment of the Coal Beneficiation. *South African Institute of Mining and Metallurgy Journal*. Volume/ Issue: 1282, pp. 356-364.

GODDARD, W. & MELVILLE, S. 2005. 2nd ed. *Research Methodology (An Introduction).* Durban: Juta.

GOLDRATT, A. Y. 2001-2009. *The theory of constraints and its thinking process: A brief introduction to Theory of Constraints (TOC):.* Goldratt Institute (AGI). [Online]. <Available at:< www.goldratt.com/toctpwhitepaper.pdf>. Accessed: 3 May 2008.

GOUSSARD, L. 2009. New berth 306 expands capacity of RBCT. *Civil Engineering,* May, p .8.

GOVIL, M. & PROTH, J. M. 2002. *Supply Chain Design and Management*. San Diego (CA): Academic Press.

GREEF, A. 2005. Public research and regulation initiatives. [0nline]. Available at: www.powerbase.info/...Public_Research_and_Regulation_Initiative.> . Accessed: 18 February 2010.

GRUNWALD, M. 2009. Going Nuclear. *Time Magazine*, 12 January, pp.25-26.

HAMMERSLEY, M. 2008. *Questioning Qualitative Inquiry (Critical Essays).* London: Sage.

HANDFIELD, R. B. & NICHOLS Jr., E. L. 2002. *Supply Chain Redesign*. Upper Saddle River: Financial Times Prentice Hall.

HARSCH, E. 2009. Africa heads to Copenhagen with coherent strategy. *United Nations African Renewal/The Star,* 25 November,pp.5.

HEIZER, J. & RENDER, B. 2008. 9th ed. *Operations Management*. Upper Saddle River (NJ): Pearson Education.

HICKS, B. 2008. *The Dirt on Coal*. Energy and Capital, 27 May. Baltimore: Angel Publishing.

HOPP, W. J. 2008. *Supply Chain Science*. New York: McGraw-Hill/Irwin.

HUGOS, M. 2006. 2nd ed. *Essentials of Supply Chain Management.* Hoboken (NJ): John Wiley & Sons.

HUGO, W. M. J., BADEHORST-WEISS, J. A. & VAN BILTON. 2004*. Supply chain management (Logistics in perspective).* Pretoria: Van Schaik.

HUSSEY, J. & HUSSEY, R. 1997. *Business Research: A practical guide for undergraduates and postgraduate students.* New York: Palgrave.

Illinois Department of Commerce and Community Affairs. *Illinois Coal and Clean Technologies*. Office of Coal Development and Marketing. [Online]. Available at: <http://www.coaleducation.org/lessons/sec/Illinois/cleanil.htm>. Accessed: 16 June 2009.

Inside Mining. 2010. A cleaner future for coal, 4 May, p.17.

IOANNOU, G. & PAPADOYIANNIS, C. Theory of constraints-base methodology for effective ERP implementation. *International Journal of Production Research*. Vol. 42. No. 23, pp. 4927-4954.

JAIN, V. & BENYOUCEF, L. 2008. Managing long supply chain networks: Some emerging issues and challenges. *Journal of Manufacturing Technology Management.* Vol. 19 No. 4, pp.469-496.

JENKINS, S. H. & HANSEN, P. S. 1993. Solid Waste from Coal Fired Power Plants*:* Water Pollution Problems*. Water Science and Technology.* Volume 10 & 15. November 11.

JESTON, J. & NELIS, J. 2008. 2nd ed*. Business Process Management (Practical Guideline to Successful Implementation).* Oxford: Elsevier.

JIANG, H. ZHOU, M. & MENG, J. 2007. The Study on Structure and Characteristics of Coal Supply Chain. *School of Management, Cumt, China*.

KAMPSTRA, R. P., ASHAYERI, J. GATTORNA, J. L. 2006. Realities of supply chain collaboration*. The International Journal of Logistics Management* Vol. 17 No.3, pp.312-330.

KANE, M. & TROCHIM, W. K. M. 2007. *Concept Mapping for Planning and Evaluation.* Thousand Oaks (CA): Sage.

KEYSER, M. J., CONRADIE, M., COERTZEE, M. & van DYK, J. C. 2006. Effects of Coal Particle Size Distribution on Packed Bed Pressure Drop and Gas Flow Distribution*.* Elsevier. *Fuel Journal.* Vol. 85 pp. 1439-1445.

KHUZWAYO, W. 2010. Disparity in mining industry. *The Star, Business Report*, 7 April, p.1.

KING, M. & LESSIDRENSKA, T. 2009. *Transient Care Takers: Making Life on Earth Sustainable.* Johannesburg: Pan Macmillan.

KIRKUP, J. & GRAY, L. 2009. New Planning Rules Allow for 6000 Out-shore Turbines. *Daily Telegraph. Weekly (World Edition).* July 22-28, p. 10.

KLEIN, M. 2009. Steely Resolve to Ride out the Storm in a Soft Market: Steelmaker Perks up After an Awful 2007*. Sunday Times, Business Times*, 15 February.

KRALGIC, I. 1992. Pesticide reactivity toward hydroxyl and its relationship to field. [Online]. Available at: pubs.acs.org/doi/abs/10.1021/jf950423y>.Accessed: 14 April 2009.

KRUGER, P. 2006. *Alternative Energy Resources: The Quest for Sustainable Energy.* Hoboken (NJ): John Wiley & Sons.

KVALE, S. & BRINKMANN, S. 2009 2nd ed*. Interviews (Learning the Craft of Qualitative Research Interviewing).* Thousand Oaks (CA): Sage.

LANE, T. 2010. Sustainable approach to freight in South Africa. *Supply Chain Today*, June, pp.32-33.

LANG, J. 1995. *Coal Mining in the Life of South Africa*. Cape Town: Jonathan Ball.

LANG, S. 2009. High stakes battle between mining and environment. IPS Inter Press Service. [Online.]Available at: http://ipsnews.net/print.asp?idnews=39470 > Accessed: 23 June 2010.

LANGFORD, J. 2006. 2nd.ed. *Logistics Principles and Applications*. New York: McGraw-Hill.

LASHINSKY, A., SCHLOSSER, J. & WOODY, T. 2009. Does Clean Coal Exist? *Fortune Magazine* (European Edition), June.

LEE, N. & LINGS, I. 2008. *Doing Business Research: A Guide to Theory and Practice.* London: Sage.

LEEDY, J. & ORMROD, E. 2010. *Basic Principles of Research: Choosing the right method of research.* New York: Pearson.

LEENDERS, M.R., JOHNSON, P.F. FLYNN, A.E. & FEARON, H.E. 2006. 13TH ED. *Purchasing and Supply chain management: with 50 supply chain cases*. New York: McGraw Hill.

LENNON, S. J. 1997. Clean coal technology choices relating to the future supply and demand of electricity in Southern Africa*. Journal of Energy R&D in Southern Africa.* Vol. 28, pp.45-51.

LEPORE, D. & COHEN, O. 1999. Deming and Goldratt: The Theory of Constraints and the systems of profound knowledge. *North River Press*, pp.43-57, (Dr. Youngman webpage 2003-2009).

LI, A-B., ZHOU, M. & QIN, F. 2007. The study of green logistics of coal enterprises based on circular economy. International Conference *Waste Management, Environmental, Geotechnology and Global Sustainable Development* (ICWMEGGSD'07) LJUBLJANA, Slovenia, August 28-30.

LIMPITLAW, M., AKEN, H., LODEWIJKS, H. & VILJOEN, J. 2005. Post-mining rehabilitation, land use and pollution. *The South African Institute of Mining and Metallurgy*.

LINDERMAN, C.W. & BLUME, E.R., 2007. Keep coal on track. *Electric Perspectives*, November/December issue 6 ABI/INFORM Global.

LLOYD, P. J. 2002. *Coal mining and environment*. Energy Research Institute, University of Cape Town.

LOK, G. 2009. Demand vs energy supply. *Inside Mining*. November/December.

MALINKEWITZ, B. 2008. Mining a field trip. Electronic Journal – [Online.] Available at: <http://www.steinkohleportal.del/en_context.phd?id=1608. > Accessed:June 2008.

MANDERS, P., GODFREY, L. & HOBBS, P. 2009. Acid mine drainage in South Africa. *CSIR (Our Future Through Science),* August p.1.

Map Studio South African Road Atlas, 14th ed. [Online.] Available at: <www.mapstudio.co.za>.Accessed;(DATE MISSING)

MARTIN, A. J. 2001. Capacity Planning - The antidote to supply chain constraints. Supply Chain Management Review. November/December. pp.62-76. [Online.] Avaialble at: < www.scmr.com>.Accessed:(DATE MISSING)

MATHEWS, C. 2009. South African Coal Suspends Mining as Demand and Price Fall. *Business Day.* Ref No. 3551. 31 March.

MAXWELL, J. A. 2005. 2nd ed*. Qualitative Research Design: An Interpretive Approach.* Thousand Oaks (CA): Sage.

MBendi Newsletter. 2010. The world after 2020., pp.1. [Online]. Available at: <http://us.mg2.mail.yahoo.com/dc/launch?.gx=1&.rand=1418899084.>. Accessed: 6 August 2010.

McCOLLUM, D. L. & OGDEN, J. M. 2009. Future Forecasts of Coal Distribution Constraints on Coal Costs. Elsevier, pp.460-471. *University of California-Davis,* Davis, California 95616.

McDONALD, D. A. 2002. *Environmental Justice in South Africa.* Cape Town: University of Cape Town.

MENTIS, M. T. 2006. Restoring native grassland on land disturbed by coal mining on the Eastern Highveld of South Africa*. South African Journal of Science* 102, May/June.

MERRIAM, S. B. 2002. Introduction to qualitative research. [online]. Available at: www.scrib.com.../introduction-to-Qualitative-Research-Merriam-2002>. Date Accessed: 21 October 2009.

MODARES, A. & SEPEHRI, M. 2009. Development of integrated system for distribution planning in supply chain. *South African Journal of Bususiness Management*, 40 (4).

MOHR, P. , FOURIE, L. & Associates. 2008. *Economics for South African Students*. 4^{th} ed. Pretoria: Van Schaik.

MOLTENO, C. 2008. How best to meet South Africa's future energy requirements. *Transactions of the Royal Society of South Africa. Vol. 63 (2),* Cape Town, pp.189-191.

NATIONAL ENERGY REGULATOR OF SOTH AFRICA (NERSA). 2008a. Inquiry into the National Electricity Supply Shortage and Load Shedding. 12 May.

NATIONAL ENERGY REGULATOR OF SOUTH AFRICA (NERSA). 2008b. Annual Report.

NATIONAL ENERGY REGULATOR OF SOUTH AFRICA. 2009. Annual Report.

NEUMAN, W. L. 1997. Social research methods: Qualitative. [Online]. Available at: <hhttp://getcited.net/cits/pp/1/PUB/100104405>. Accessed: 27 February 2002.

NISNEVICH, M., SIROTIN, G., SCHLESINGER, T. & ESHEL, Y. 2008. Radiological Safety Aspects of Utilising Coal Ashes for Production of Lightweight Concrete*. Fuel Journal.* Vol. 87, Issue 8-9 July, pp.1610-1616.

PIPERE, A. 2006.*Education and sustainable development (First step towards changes*). Latvia: Dongav pils University.

PORTER, M. E. 1985. *Competitive strategies.* New York: Press.

Ports SA. 2007. Black Gold*.* Quarterly Publication (Autumn).

PRESSLY, D. 2010. MPs haul TRANSNET over the coals for Cape gauge delay. *The Star*, 2 June. pp.16.

PREVEC, R. 2006. The Power of Plants: How Ancient Forests Drive South Africa's Economy. *Science in Africa Magazine*. February.

PREVOST, X. 2008. Coal mining in South African*. Inside Mining*, pp.6-9.

PREVOST, X. 2009. Underground coal gasification. *Inside Mining,* September, pp.7-9.

PREVOST, X. 2010. A clean future for coal. *Inside Mining,* April/May, pp.14-17.

PRINSLOO, L. 2009. Calls for further research into dry coal beneficiation growing. *Mining Weekly*, 27 March, p.16..

PRICEWATERHOUSECOOPERS. 2010. KING'S COUNSEL: Understanding and unlocking the benefits of sound corporate governance in government and the public sector. 20 February.

PYCRAFT, M., SINGH, H., PHIHLELA, K., SLACK, N., CHAMBERS, S., HARLAND, C., HARRISON, A. & JOHNSON, R. 2003. *Operations Management*. Cape Town: Pearson, SA.

QUAYLE, M. & JONES, B. 1999*. Logistics: An Integrated Approach*. 2nd ed. Newcastle Upon Tyne: Athenaeum.

REPUBLIC OF SOUTH AFRICA (RSA). Department of Transport. 2006a. *Interventions to reduce freight and passenger transport costs.* Pretoria: Government Printer.

REPUBLIC OF SOUTH AFRICA (RSA). Department of Environmental Affairs and Tourism. 2006b. *Environmental Management Plan (EMP).* Government Gazette No. 28753. Vol. 490. Pretoria: Government Printer.

REPUBLIC OF SOUTH AFRICA (RSA). Department of Minerals and Energy. 2007/2008. *South Africa's Mineral Industry (SAMI*). Pretoria: Government Printer.

REPUBLIC OF SOUT AFRICA (RSA). Department of Minerals and Energy. 2009a. *Operating and Developing Mines in the Republic of South Africa*. Directory D2. Pretoria: Government Printer.

REPUBLIC OF SOUTH AFRICA (RSA). Department of Minerals and Energy. 2009b. *Growth Prospects of South Africa's Coal Exports and the effects on the Black Economic Empowerment Companies*. Report R77. Pretoria: Government Printers.

REPUBLIC OF SOUTH AFRICA (RSA). Department of Mineral Resources. 2009c. *Molato (Banna le Basadi ba tlile go tlo rera Molato).* Johannesburg: Primedia.

REPUBLIC OF SOUTH AFRICA (RSA). 2009d. Green Paper: National Strategic Planning. Planning: The Presidency.

REPUBLIC OF SOUTH AFRICA (RSA). Department of Transport. 2010a. Strategic Plan 2010/11- 2012/13. Pretoria: Government Printer.

REPUBLIC OF SOUTH AFRICA (RSA). Department of Mineral Resources. 2010b. Mining Licenses Moratorium No. 33511, Vol. 542, Pretoria, 31 August.

Resource. 2010. Energy usage and climate change. May, pp.16/18.

RICHARDS BAY COAL TERMINAL (RBCT). 2008. Richards Bay Coal Terminal Increases Coal Export Capacity. 4 January. [Online] Available at: <www.rbct.co.za>. Accessed: 4/1/2008.

ROBSON, C. 2002. Qualitative research. [Online]. Available at: <www.cs.umd.edu/.../CMSC735%2011a%20Qualitative%20Analysis.pdf>. Accessed: 18 August 2004.

ROLAND, J. 2010. Liquid fuel. World coal. [Online] Available at: <www.futurecoalfuels.org/news.asp >. Accessed 5 July 2010.

RUSHTON, A., CROUCHER, P. & BAKER, P. 2006. 3rd ed. A *Handbook on Logistics and Distribution Management*. London: Kogan Page.

SADLER, I. 2007. *Logistics and Supply Chain Integration: Business and Economics*. London: SAGE.

SALGADO, I. 2009a. Nuclear Power Time Table Sketched. *The Star, Business Report*, 26 May, p.2.

SALGADO, I. 2009b. South Africa's Climate Shift Policy Rates High. *The Star, Business Report*, 2 July, p. 5.

SALGADO, I. 2009c. South Africa Lags Far Behind in Funding for Clean Energy. *The Star, Business Report*, 21 July, p. 5.

SALGADO, I. 2009d. Climate Goalposts Move While Leaders Argue Details. *The Star, Business Report,* 28 July, p. 2.

SALGADO, I. 2009e. SA defends basic stance at the UN talks. *The Star, Business Report,* 23 December, p.15

SALGADO, I. 2010a. State clarify emissions target. *The Star, Business Report,* 27 January, p.19.

SALGADO, I. 2010b. Grootvlei's acid waters show pitfalls of old mines. *The Star, Business Report*, 21 May, p.8.

SALGADO, I. 2010c. Economists fail to see the extraction is exhausting. *The Star, Business Report*, 28 September, p.2

SASOL.2004. Annual Report.

SASOL Report. 2007.[Online.] Available at: <http://www.sasol.co.za>. Accessed: 7 February 2009.

SASOL. 2008. Sustainable Development Report.

SASOL 2009. Annual Report.

SAUNDERS, M. LEWIS, P. & THORNHILL, A. 2003. 3rd ed. *Research Methods for Business Students.* Essex: Pearson.

SENGPIEHL, C., OAKDEN, R., NAGEL, P., TOH, K. T. K. & SHI, P. 2008. The emergence of logistics cities: Conceptual model. *Journal of Transport and Supply Chain Management,* November.

SHAH, J. 2008. Supply chain risk management: Academic Perspective. Supply chain management: Discussions. *IIMB Management Review*, June, pp. 149-157.

SIMCHI-LEVI, D., KAMINSKY, P. & SIMCHI-LEVI, E. 2008. 3rd ed. *Designing and Making the Supply Chain: (concepts, strategies and case studies*). New York: McGraw-Hill/Irwin.

SIMUTAPANG, T. M., WRIGHT, A. C. & SRIDHARAN, R. 2004. Applying the Theory of Constraints to Supply Chain Collaborations*. Supply Chain Management. An International Journal.* Volume 9. Number 1. Pp.57-70.[Online.] Available at: <www.emeraldinsight.com/1359-8546.htm>. Accessed;(DATE MISSING)

SINGH, N. & BEUKES, J. 2005. Examine coal mine research in South Africa. Coaltech. *International Mining*, September, pp.38-40.

Source Watch. 2009. Very low sulphur content.[Online.} Available at: <http://www.sourcewatch.org/index.phd?title=very_low_s > Accessed: 15 June 2009..

SMUTS, W. 2008. Why coal is once again King. *Inside Mining,* September, pp.33-37.

SRIDHARAN, R. & SIMATUPANG, T.G. 2009. Managerial views of supply chain collaboration. *International Journal of Business.* Gadjah Mada.May-August, Vol. 11, No. 2, pp. 253-273.

STOCK, J. R. 2009: A research view of supply chain management: Developments and topics for exploration. Department of Marketing, College of Business, *University of Florida.* Volume 25 (2), pp.147-160.

STROH, M. B. 2006. 3rd ed. *A Practical Guide to Transportation Management and Logistics.* Dumont (NJ).

Sunday Independent. 2008. Coal mining, exploration, plan and environment protection in South Africa. June 16.[Online.] Available at: < http://www.paguntaka.org/2008/06/16/coal mining-exploration-plan-and-environment-protection> Accessed: 23 June,2010.

SUPER GROUP: 2005. MRP, MRP II & the whole supply chain thing. *An Overview*, 19 October.

SWAMINATHAN, J. M., SMITH, S. F. & SADEH, N. M. 1998. Modeling supply chain dynamics: A multi-agent approach. *Decision Sciences;* Summer 1998; 29, 3; ABI/INFORM Global.

TALJAARD, N. 2005. Supply chain and logistics management. *TWA*, March/April, pp.17-18.

TERBLANCHE, S. 2008. Adapting for climate change. *Leadership in Local Government*, January/February,pp.17.

THORPE, R. & HOLT, R. 2008. *The Dictionary of Qualitative Research*. London: Sage.

TRANSNET. 2007. Annual Report.

TRANSNET. 2008. Annual Report.

TRANSNET. 2009. Annual Report.

TZENG, G-H., HWANG, M-J. & TING, S-C. 1995. Taipei's Coal Logistics System. *An International Journal of Physical Distribution & Logistics Management*. Taipei, Taiwan.

TZENG, G-H., TEODOROVIC & HWANG, M-J. 1996. Fuzzy Bacteria Multi-Index Transformation Problems for Coal Allocation Planning of Taipower. Energy and Environmental Group and Institute of Traffic and Transformation. *National Tung University,* Taipei, Taiwan.

UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC). 2009. Climate change Accord at Copenhagen, Denmark, December.

UNITED STATES POPULATION ENERGY AND CLIMATE CHANGE. 2008. One key link between population and climate change. [Online]. Available at: <www.cepnet.org/.../USPopulationEnergyandClimateChangeReportCEP.pdf>. Accessed: 9 September 2008.

UNITED STATES CENSUS BUREAU. 2010. Population census. [Online]. Available at: <www.census.gov/compendia/statab/cats/population.htlm.>. Accessed: 20 January 2011.

VADAPALLI, V. R., GITARI, W. M., ELLENDT, A., PATRICK, L. F. & BALFOUR, G. 2008. Synthesis of Zeolite-P from coal fly ash derivative and its utilisation in mine-water remediation. Research Article. Vol. 106 No.5/6 pp.1-7 [Online.] Available at:< http://www.sajs.co.za>. Accessed: 9 June 2010.

VAN DER KLAUW, H. 2009. Coal Rail Infrastructure Master Plan (CRIMP). *Queensland Rail Network*. Australia. October, pp.17-29.

VAN DYK, E., ITTMANN, H., MARAIS, M., MEYER, I. & MASPERO, E. 2008. The state of logistics: Research priorities for sustained improvement. *Journal of Transport and Supply Chain Management, November,* pp.93-106.

VAN SCHALKWYK, M. 2008. Adapting to climate change. *Leadership in Local Government Journal*., January/February, pp. 7-18.

VAN VUUREN, L. 2009. Coal Mining's Impact on Waterberg Under Microscope. The *Waterwheel Journal*, March/April, pp. 14-14.

VAN WEELE, A. J. 2003. 3rd ed. *Purchasing and Supply Chain Management (analysis, planning and practice*). London: Thomas Learning.

VAN WEELE, A. J. 2005. 4th ed. *Purchasing and Supply Chain Management (analysis, strategy, planning & practice).* London: Thomas Learning.

VIREN, C., ANDREW, K. & SREEKANTH, J. 2006. Impact of Coal Mine Dump Contaminated Soil on Elemental Uptake by Spinacia Oleracea (Spinach*). Journal of Environmental Science & Health,* Part B- Pesticides, Food Contaminants & Agricultural Wastes: April, Vol. 41 Issue 3, pp. 297-307.

VOGT, J. J., PIENAAR, W. J. & DE WIT, P. W. C. 2005. 2nd ed. *Business Logistics Management: theory and practice.* Cape Town: Oxford University Press.

WADSWORTH, Y. 1997. Introduction to social research method. [Online]. Available at: <www.waterstones.com/waterstonesweb/...wadsworth/5407663/>. Accessed: 11 January 1997.

WALLER, D.L. 2003. 2nd ed. *Operations Management*. London: Thomas Learning.

WALTERS, D. 2009. Understand the value chain network, understand the market, understand the industry and understand the customer. *Journal of Transport and Supply Chain Management*, November.

WATERS, D. 2007a. 5th ed. *Global Logistics.* London: Kogan Page.

WATERS, D. 2007b. *Supply Chain Risk Management (Vulnerability and Resilience in Logistics).* London: Kogan Page.

WEFA (Primark Company). 2000-2001. Coal Mining. Industry Yearbook.

WEST, B. & LAFFERTY, T. 2007. Adopting a customer-focused and process-centric supply chain. *Hydrocarbon Processing*, January, pp.101-108.

WILHELM, A. 2008. Challenging conventional wisdom. *Inside Mining*, August. p.17.

WILHELM, A. 2009. Coal is still King. *Inside Mining*, pp.6-9.

WIJAYATUNGA, P. D. C. *et al*. 2006. Energy Conversion and Management. 47, pp. 1179-1191.

WISE, D. & FAGAN, M. 2001. Successful supply chain management. *Rail Age*, April, pp.60-61.

WILLIS, J. W. 2007. *Foundations of Qualitative Research (Interpretive and Critical Approach*). London: Sage.

World Bank Group. 2007. Environmental Health and Safety Guidelines. Report, 30 April

World Bank Group.1998. Coal mining and production (Pollution prevention and abatement handbook), July.

World Coal. 2010. Clean coal technology. E- newsletter Pt. 2. [Online]. Available at: <http://us.mg2.mail.yahoo.com/dc/launch?.gx=1&.rand=13253977&retry=1>.Accessed: (DATE MISSING)

World Yearbook. 2000. Central Intelligence Agency. Washington, DC.

XSTRATA. 2008. Annual Report.

ZACHARIA, Z. G., NIX, N-W. & LUSCH, R. F. 2009. An analysis of supply chain collaborations and their effects on performance outcome. *Journal of Business Logistics,* Vol. 30. No. 2, pp.101-123.

ANNEXURE 1:

RESEARCH INTRODUCTION LETTER

Dear Sir/Madam,

RE: RESEARCH INTRODUCTION LETTER

As the Research Professor in the Faculty of Management Sciences at the Vaal University of Technology I wish to introduce to you our doctoral student Ken Mathu who is currently undertaking a research project titled: "**Supply chain constraints in the South African coal mining industry"**. I wish to invite you to participate in this very important study by way of an interview.

This study is important due to the role played by coal in South Africa and other countries as a crucial energy source and its impact on the global climate change. The study will explore the constraints/bottlenecks experienced in the coal industry supply chain with a view to establishing a model that would minimise such constraints.

The interview should take between 30-50 minutes and strict ethical guidelines will be adhered to. A digital voice recorder will be used to record the interview process in order that we can verify the recorded transcripts and facilitate data analysis.

As a condition for the qualification, the researcher has undertaken to adhere to all ethical issues pertaining to confidentiality, nondisclosure and anonymity and this letter serves to provide such undertakings. The information related to the interviews will not be accessible to anyone else except to his supervisors Drs David Pooe and Andrea Garnett, both of the Vaal University of Technology.

The results of this study will be made available to you on request. Your participation in this study will be of benefit since it will contribute towards the minimisation of constraints currently faced by the South African coal mining industry and thus ensuring that the country will be able to meet its energy needs going forward.

On acceptance, the researcher Ken Mathu will introduce you to the research process, sample questionnaire and the study time frame so that an appropriate interview date can be set.

Thanking you in anticipation for your valuable role in this project.

Yours faithfully,

____

Professor Babs Surujlal

Research Professor

Faculty Management Sciences

Tel: (016) 930 5050

Fax: 086 6128 627

Email: babs@vut.ac.za

INTERVIEW ACCEPTED:

Company/ institution: ______________________________

Name of respondent: ______________________________

Tel: ______________________________

E-mail: ______________________________

ANNEXURE 2:

RESEARCH QUESTION/ QUESTIONNAIRE

INTERVIEW QUESTIONS

1. How would you describe the South African coal mining industry presently?
2. Describe your organisation/Institution's coal supply chain.
3. Describe the supply chain constraints/bottlenecks experienced by your organisation/institution.
4. What are the green (environmental) issues relevant to your organisation/ institution and how does your organisation/institution manage them?
5. Explain how your organisation/ institution manages reverse logistics, in other words stocks that have to be returned because it cannot be used for further processing.

ANNEXURE 3:

PROOF OF LANGUAGE EDITING

ASOKA ENGLISH LANGUAGE EDITING

सत्यमेव जयते

DECLARATION

This is to certify that I have English Language edited the thesis

Supply chain constraints in the South African coal mining Industry.

Candidate: Mathu, K.

Prof. D. Schauffer

SATI member number: 1001872

DISCLAIMER

Whilst the English language editor has used electronic track changes to facilitate corrections and has inserted comments and queries in a right-hand column, the responsibility for effecting changes in the final, submitted document, remains the responsibility of the candidate in consultation with the supervisor.