

# Transportation Demand Analysis of Coal from Hwange Coal Fields

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**Abstract**— This paper seeks to provide a background to the coal and coke manufacturing industry in Zimbabwe after the economical melt down of 2007. It analyses the current situation in terms of coal and coke supply and to identify the factors that affect coal and coke transportation choices. Results of the survey of the coal and coke suppliers were tabulated and factors which affect transportation such as method of loading, payment plans, reliability and strategic alignment of the transporter were analysed. Model recommendations on a strategic supply chain management approach were given for the agricultural sector and for the manufacturing sector with the aim of reducing heavy loads on the road and minimizing emissions by trucks while still maintaining high productivity..

**Index Terms**—Transportation, strategic supply chain, coal

## I. INTRODUCTION

Production of coal in Zimbabwe since 1980 was characterized by an increase in tonnage up to around 1996 as shown in Fig 1. This was followed by a decrease in production with the lowest value reached in 2009.

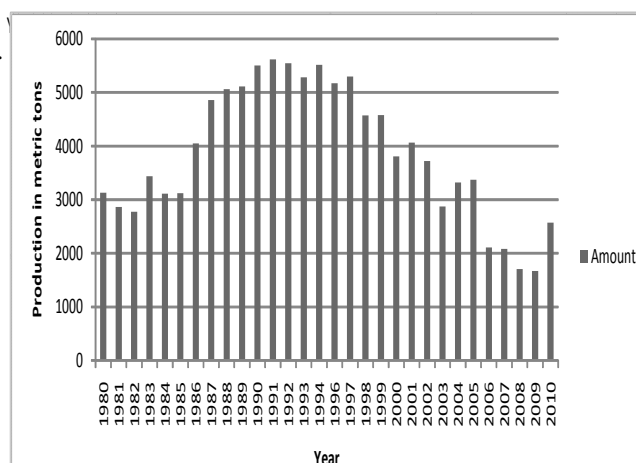


Fig. 1. Coal production in Zimbabwe in metric tonnes (1980 – 2010) [1]

The political and economic situation in Zimbabwe between 2000 and 2007 was characterised by fiscal deficit, unstable exchange rate and soaring inflation which was 7635% in July 2007 [2]. Inflation was estimated at 2 000

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000% in 2008 [3]. During the year 2009 the multi-currency was introduced in the country resulting in stability in the currency and an increase in economic growth with GDP values of 5.8% in 2009, 8.1% in 2010, 9.3% in 2011 and an estimate of 4.7 in 2012 [4]. This was as a result of the formation of Government of National Unity (GNU). During the same period breaking of monopolies was seen with new players coming into the coal industry. There was also the discovery of diamond which has stimulated economic growth in the country. There was an increase in demand for electrical power. This increase in demand for power has seen the re-sustaining of agricultural activities especially in the area of tobacco farming and thus the increase in the demand of coal for curing of tobacco. All the above factors stimulated the need to provide transportation of coal to the clients via any mode of transport. At the current moment Zimbabwe generation is about 1200MW against demand of 2200MW at peak periods thus the refurbishing of the small thermal power stations in Harare, Munyathi and Bulawayo [5].

The research is set out to answer the following question: What is the current situation and the projection of demand of coal from the Hwange coal fields? What is the current ratio of mode of transportation between road and rail freight?

Coal mining in Zimbabwe has been previously dominated by Hwange Colliery Company Limited (HCCL). With the liberalization of the economy more players came in and this resulted in an increase of demand on transportation from the mining fields. Currently the coal companies have been divided into coal mining companies and coke making companies. The coal mining companies are namely; HCCL, WK Blasting (WK), Makomo Resources, Clidder and Liberation while the coke making companies are HCCL, Hwange Gasification, and South Mining. Thus, the need for a relook at the demand for transport by the coal companies and methods to solve the problem where transportation becomes the bottleneck in the coal and energy supply chain. Much of the need for coal has been for electricity generation. The need for more electricity was noted as early as 2000 and the projected plans for the coming decade were set [6].

A comparison with the neighbouring countries is shown in Table I to reflect coal production in SADC region. Of the five countries in comparison there is some indication of coal importation meaning there is failure to satisfy demand by local production or importation is cheaper than local production. Within the five countries it can be noted that the location of the coal deposits and the demand are different.

TABLE I  
COAL STATISTICS BY YEAR FOR SOUTH AFRICA, BOTSWANA,  
MOZAMBIQUE, ZIMBABWE AND NAMIBIA BETWEEN 2006 AND 2010) [7]

	Coal in South Africa	Coal in Botswana	Coal in Mozambique	Coal in Zimbabwe	Coal in Namibia
Exports 2010	76,683	-	6	220	-
Imports 2010	2,088	3	-	12	158
Production 2010	280,788	814	42	3,304	-
Consumption 2010	206,193	817	36	3,095	158
Exports 2009	73,768	-	6	220	-
Imports 2009	2,016	3	-	46	213
Production 2009	276,219	814	42	3,304	-
Consumption 2009	204,468	818	36	3,163	213
Exports 2008	66,135	-	6	219	-
Imports 2008	2,651	3	-	47	455
Production 2008	278,017	1,003	42	3,350	-
Consumption 2008	214,533	1,008	11	3,207	455
Exports 2007	72,606	-	24	219	-
Imports 2007	1,975	17	-	51	85
Production 2007	273,005	913	26	3,568	-
Consumption 2007	202,374	929	10	3,415	85
Exports 2006	75,781	-	23	228	-
Imports 2006	2,043	19	-	54	71
Production 2006	269,817	1,060	45	3,800	-
Consumption 2006	196,079	1,079	-	3,628	71

In Zimbabwe there has not been any analysis of transport and electricity generation based on coal. The need to analysis the effect of transport cost as related to electricity generation was undertaken for China [8]. Bilgen [9] looked at modeling of a blending and marine transportation planning problem with fuzzy mixed-integer programming. Rail freight traffic, its affect on future impacts of coal distribution and constraints on coal costs was further analysed in [10]. Broskii [11] developed the balance of supply in the Russian market for coking-coal concentrates. This looked into the best model in order of enrichment facilities from the mine during the planned period. Power coal transportation and storage was analysed comparing the road and rail options in [12]. There has been analysis of coal transportation cost [13]. Havenga conducted research in South Africa comparing rail freight per segment market [14]. A summary of this analysis is shown in Fig 2.

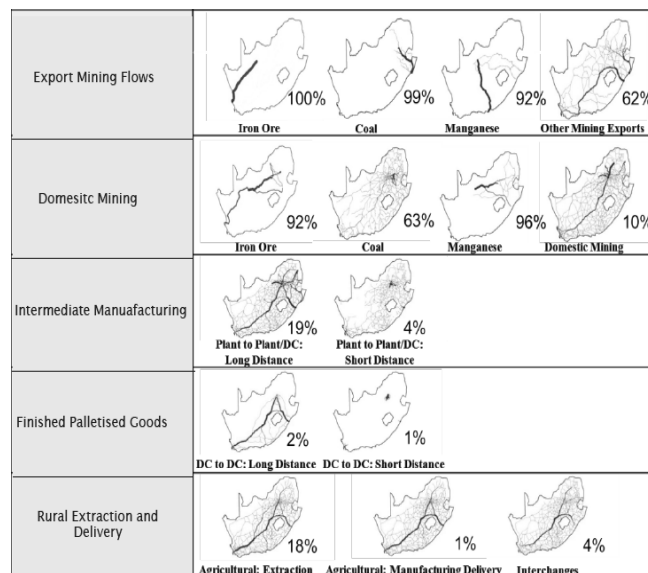


Fig. 2. Total freight flows per sub-segment in tonnage terms; rail share in percentage (2009) [14].

The Zimbabwe National Energy policy was launched in 2012. The Zimbabwe National Energy policy seeks to promote the optimal supply and utilization of energy, for socio-economic development in a safe, sustainable, and environmentally friendly manner. On the supply side the country has vast deposits of coal which are underutilized and can benefit the country in terms of economic growth, employment creation, self sufficiency and trading power within the region [15].

Before one can look at the mathematical model of Zimbabwe there was need to analyses the qualitative factors in the Hwange coal fields in terms of the transportation systems used and factors that affect that transportation system. This on its own leads to the consideration of the coal supply chain.

La Londe and Masters [16] defines supply chain strategy as including two or more firms in a supply chain entering into a long-term agreement; ...the development of trust and commitment to the relationship; ... the integration of logistics activities involving the sharing of demand and sales data; ... the potential for a shift in the locus of control of the logistics process". Monczka et al [17] define supply chain management (SCM) as a concept, whose primary objective is to integrate and manage the sourcing, flow, and control of materials using a total systems perspective across multiple functions and multiple tiers of suppliers. Supply chain orientation (SCO) is defined as the recognition by an organization of the systemic, strategic implications of the tactical activities involved in managing the various flows in a supply chain. Thus, a company possesses a supply chain orientation if its management can see the implications of managing the upstream and downstream flows of products, services, finances, and information across their suppliers and their customers [18]. A summary of the aspects of SCM is shown in Figure 3. There is need for the Zimbabwe companies to analyse and compete as supply chains than as separate companies.

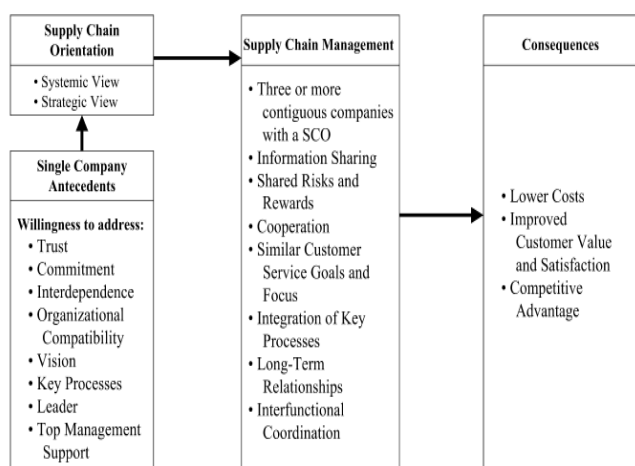


Fig. 3. Supply chain management antecedents and consequences [18]

## II. METHODOLOGY

The research method involved a critical assessment and review of existing literature, survey using questionnaires and interview with key personnel involved in logistics issues at the National Railways of Zimbabwe southern area, mining and coke making companies in Hwange. Site visits were undertaken to different sites in Hwange during the period June to August 2012. Interviews were undertaken with the major consumers and retailers. It is from this information that recommendations on managing the demand for transport were made.

The analysis did not break the coal and coke products in terms of peas, nuts and on whether they are washed or not. Further work is underway at this level that will relate to the technologies that are being used in the different companies. The aim is to develop a model that recommends technologies to be used in boilers based on the type of coal in terms of ash contents and sulphur contents.

## III. HWANGE COAL FIELDS TRANSPORTATION OPERATIONS

### A. Hwange Colliery Company Limited (HCCL)

Products come from the mines via conveyors to the processing and the coke making plants. Some are sent directly to the bunkers for transporting to the customer. The coking coal depending on the size is hand packed into bags. Foundry coking coal is in the form of big rocks. The other products such as coal peas, nuts are screened and washed before being sent to the bunkers of loading bays. The loading bays for the wagons would be under the chute and the bags after being filled are lifted on to trucks by the forklift. The company has a dedicated siding for loading wagons.

### B. Makomo Resources

Coal is brought from the open cast mine by dumpers to the crushing plant. After being washed it is stockpiled. It is transported 8km by dumpers to the Sinamatelani railway siding where it is loaded onto the wagons by front end loaders. There is need to treat coal and cover it. It is inspected by Environment Management Agency before transportation.

### C. WK Blasting

Coal is brought from the open cast mine by dumpers to the crushing plant. After being washed coal is stockpiled. When empty wagons are available coal is transported by road to the railway siding where it is loaded on to the wagons by the front end loader. There is need to treat the coal and cover it after which it is inspected by Environmental Management Agency (EMA) so that it does not pollute the environment during transportation.

### D. Clidder Mineral

The company is subcontracted by HCCL to do coal mining. HCCL has since terminated a five-year contract mining deal with Clidder Minerals. The coal deal, which has been running since 2007, was terminated at the end of October 2012. HCCL would however, continue to outsource mining equipment when necessary.

### E. South Mining

This is a coke making company which hauls coking coal from HCCL about 2km using its own transport. This coal is enriched into coke and exported to the Democratic Republic of Congo (DRC) by road in bags.

## IV. RESULTS

### A. Product tonnages

The types of commodities and current tonnages per year of the two main coal mining companies are summarized in Fig 4. Much of the industrial coal is used in the thermal power station in the country.

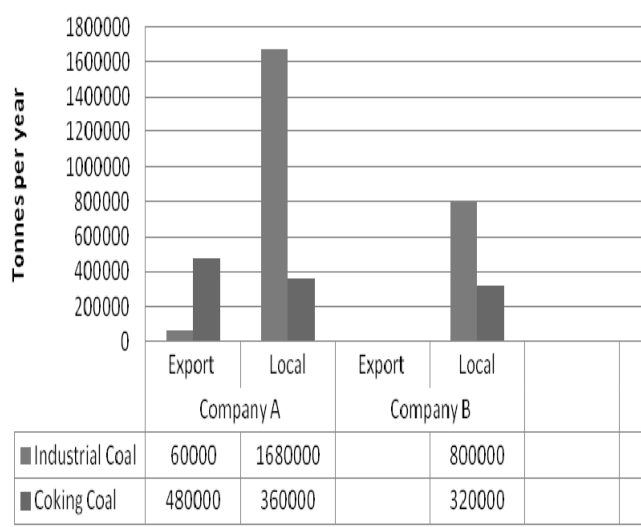


Fig. 4. Types of Commodities and current tonnages per year.

The type of commodities and projected tonnages by 2015 are shown in Fig 5. It can be seen that production is expected to double by 2015. This raise in production is expected from infrastructural investment from foreign investor mainly from China. Currently the coking coal is being processed by two joint venture companies with investors from China.

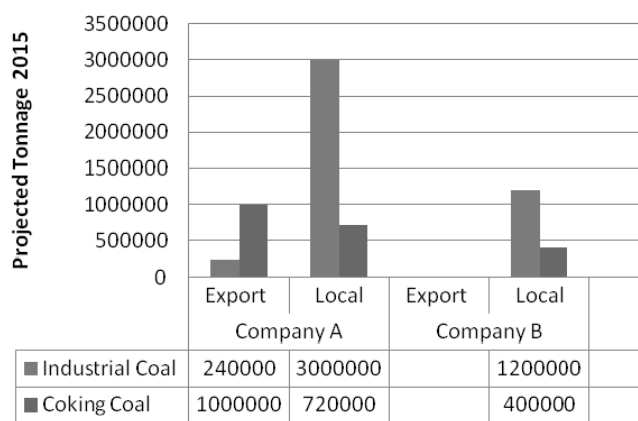


Fig. 5. Projected Tonnage Output 2015

### B. Competitive Strategy

The competitive strategies for the different companies are shown in Table II. This is necessary information as it helps freight companies to align them to what their customers feel is the most important things to win the orders.

### C. Packaging

The types of packaging used is important as it prepares that transporter to estimate the transportation cost or things

that need to be put in place to accommodate the loading process. These are summarized in Table III. It is clear that bags are mainly used for coke transportation while the loading methods are shown in Table IV.

### D. Modes of transportation used

The percentage allocation of the commodities compared to the type of transportation is as shown in Fig 6. It can be seen that road transportation accounts for the bigger share of the coal that is transported

The factors affecting choice of transportation between road and rail ranked in terms of importance are shown in Table V where 5 represent most important, 3 represent important and 1 represent less important.

For the rail transporters there was clear understanding between National Railways of Zimbabwe and Bulawayo Beitbridge Railways (BBR). The factors affecting choice of rail transporter were price, reliability and payment system. There was more emphasis on overall price and reliability as summarised in Table VI. This helps to picture the view of the private company and national company from the customers' side.

TABLE II: COMPANY COMPETITIVE STRATEGIES

		Export			Local		
		Price	Dependability	Quality	Price	Dependability	Quality
Company A	Industrial Coal				\$65/ton	Very good	Good
	Coking Coal	\$132/ton	Fair	Very good	\$115/ton	Good	Excellent
Company B	Industrial Coal				\$26.50/ton	Well dependable	good
	Coking Coal				\$58/ton		good

TABLE III: TYPE OF PACKAGING USED

	Coal Mining Companies		Coke Processing Companies		
	Company A	Company B	Company D	Company E	Company F
Wagons	x	x	x	x	x
Trailers		x	x	x	x
Tonne Bags	x		x	x	x

Company D: Company was not making coke at the time the data was not gathered due to equipment failure.

TABLE IV: WAGONS AND TRAILERS LOADING METHODS

	Company A	Company B	Company D	Company E	Company F
Front-end Loader	x	x	x	x	
Conveyor and chute	x				
Manual (for bagged products)				x	x

TABLE V: FACTORS AFFECTING CHOICE BETWEEN ROAD AND RAIL TRANSPORT.

	Company A	Company B
Factor	Rank	Rank
Price	3	3
Reliability	5	2
Quality	1	4
Infrastructure	1	5
Environmental Issues	1	1

TABLE VI: FACTORS AFFECTING CHOICE OF RAIL TRANSPORTER

	Company A			Company B		
	Price	Reliability	Payment system	Price	Reliability	Payment system
National Railways of Zimbabwe (NRZ)	x			Good	Fair	
Bulawayo Beitbridge Railways (BBR)		x				

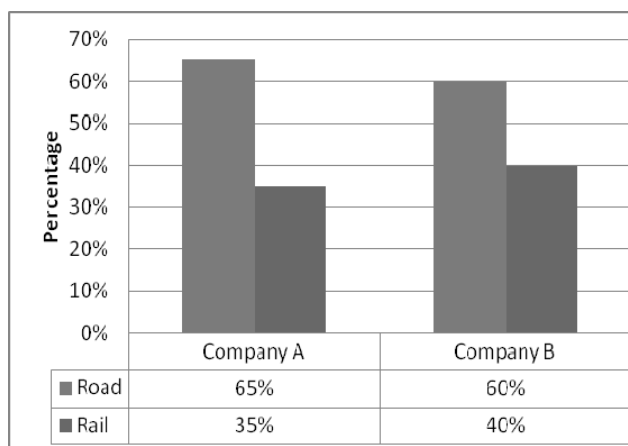


Fig. 6 Percentage allocations of commodities as compared with mode of transport.

Table VII shows the summary of the analysis of the payment system and factor that affect transport performance as related to planning and or crew scheduling.

Table VII: Payment system assessment and rail performance and its relationship with crew, trains planning and scheduling

	5	4	3	2	1
Cash before Delivery is the best mode of operation		xx			
14 Days Account System is the best mode of operation		x			
30 Days Account system is the best mode of operation	xx				
Venture capital on transportation is the way to go (investment by someone else)	x	x			
Concessions of the way to go on railway transport		xx			
Rail transportation is performing below standard or not as expected in terms of wagon turn around speed	x		x		
Rail transportation is performing below standard or not as expected in terms of capacity	xx				
Rail transportation performance are crew related		x		x	
Rail transportation performance are train planning related		xx			
Rail transportation performance are train scheduling		x	x		
Rail transportation performance are crew scheduling related		x	x		

5- Strongly Agree, 4- Somewhat Agree, 3- Neither Agree nor Disagree, 2- Somewhat Disagree, 1- Strongly Disagree

The assessment was done for the two major suppliers of coal as all the coke making companies were using road transport to carry coke across the border. The other fact the has led to coking making companies using road transportation is the unavailability of export worthy wagons that can be certified to cross into the neighbouring countries. In terms of payments plans it can be seen that the account system was favoured by the clients than the cash on delivery system. On the account system it was found out that the 30 day account system was highly favoured. This in turn will help in the planning process for the trains as there will not be traffic that is available but not movable due to non-payment for transportation. Non-movable traffic would lead to low turn-around time for the limited resources.

There is agreement that there is a strong need to increase the capacity of rail transportation. In the case of crew relationship with performance of the rail transportation it

was not clear that the clients could see the relationship with performance. It was also generally agreed that rail transportation performance is influenced by train planning, scheduling and crew scheduling.

#### V. SUPPLY CHAIN MODELS DEVELOPED

The basic coal supply chain model is a case where the coal is supplied by the miners or the coke making companies and it is transported to the Customers as shown in Fig 7. Due to the dollarization in Zimbabwe the customers have tried to keep minimum stock or tied up cash. This has led to use of quick and reliable road transportation for customers in the manufacturing sector. Whilst customers in the agricultural sector have tried to minimize cost, thus opting for the cheaper rail transportation. Thus, two conceptual models have been recommended depending on the sector.

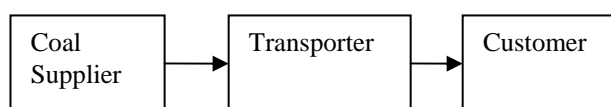


Fig. 7 Basic Supply chain

Fig 8 shows the supply chain recommendations for the agricultural sector which does not have limited storage and is characterised by seasonal demand. Some of the agricultural customers have sidings thus can have a rail delivery straight to their siding. The road transportation is recommended for emergency shortfalls. Road transportation will still be used from the Retailer stockpile to the customers.

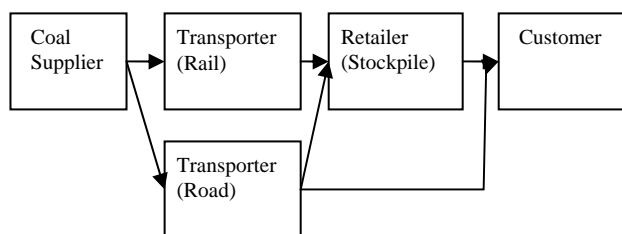


Fig. 8 Supply Chain for Agricultural and Mining Sector

Fig. 9 shows the current situations for the manufacturing sector which is characterised by no sidings, small storage areas and year round demands. Due to the unreliability of the rail transportation the sector has resorted to road transportation.

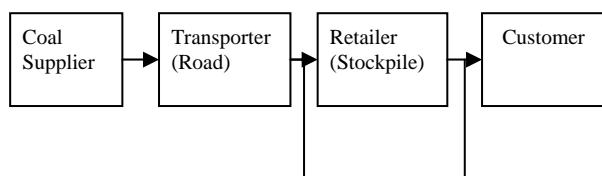


Fig 9 Current Supply Chain for Manufacturing Sector

#### VI. RECOMMENDATIONS FOR IMPROVEMENT

For the road transporters it is recommended that they ensure all products are tarpaulin-covered and no spillage on the roads. There was also recommendation of good road infrastructure and more maintenance of the roads by the Ministry of Roads. Further investigation would be necessary

to establish the limits of who owns the roads the mines or Ministry of Transport.

For the rail transporters it was recommended that there be improvement on turnaround times, which are the topical point with customers who are being forced to use road transport, which is more expensive, as a result. There is need to extend infrastructure to eliminate road transport to the siding (currently 8km of road). There is need is to increase the wagons thus the capacity and at the same time reduce defective wagons that may lead to derailment. The clients also highlighted the need for more locomotives and reduced fuel shortage.

The transportation companies should study the antecedents of the coal miners and coke producers. The Rail Freight Company needs to ensure the trust and commitment of the coal companies besides making long term contracts which are currently being introduced. There is need for supply chain strategic compatibility with the suppliers that require fast delivery of commodities and the maintenance of low inventories. This can assist in achieving the economics of 'just- in-time' stock delivery both for industry and farmers. The key processes for rail transportation needed to achieve this are traction power and wagons on the hardware side and improvement of the soft side also, which includes planning and scheduling of crew thus reducing delays caused by these delays.

On the supply chain management side, it is recommended that the rail freight company improve the information sharing through a fully integrated wagon tracking system that helps the suppliers locate the whereabouts of the goods in the system at any moment in time. There is need for the rail freight company to move from being a liability to both the suppliers and the costumers by sharing the risks and the rewards through enhanced cooperation. It is recommended that there be inter-functional coordination between operations and engineering which will help the different functions have a company goal not functional goal in terms of decisions on whether locomotive needs to have a service between stations or not. Modelling analysis of the combinations of decisions needs to be undertaken before decisions are made so that the casual effects across decision can be analyzed before a strategy is implemented.

There is need for the rail freight company to synergise its strategy with the suppliers and the end user customers. The type and choice of transportation used is hinged on speed and minimization of inventory by the customers. Road transportation has tended to have a fast turnaround time and carrying coal in bags that do not require a rail siding for the end users. It is recommended that the rail freight company formulate supply chain partners who will transport in bulk and warehouse coal in the big cities and sell in smaller qualities as needed by their clients. This in turn will lead to a better planning for the locomotive and crews for the rail freight company thus improve efficiency and reduce emission by reducing the number of road freight. This will further reduce the wear and tear of the road infrastructure by putting heavy loads on the rail.

## VII. CONCLUSION

The paper set to analyse the current situation in terms of the demand for transportation at the coal field in Hwange and investigate the needs of transport by clients. The

research also set to find out the type of packaging used by the clients and how it affects the choice of transport systems used. This qualitative and quantitative work to date will be used in the formulation of a systems dynamic model which will serve as the input model for the railway planning model. Analysis of provincial demand for coal and sources of electricity generation are under way in the bid to meet global demand on green economy.

## REFERENCES

- [1] Chamber of Mines of Zimbabwe Coal Production between 1980 and 20110, <http://www.chamberofminesofzimbabwe.com/component/stats/?view=stats&min=4> (accessed 01-01-13)
- [2] Reuters. 2007. TIMELINE: Chronology of Zimbabwe's Economic Crisis September 19. Available at <http://www.reuters.com/article/2007/09/19/us-zimbabwe-inflation-idUS11992587420070919?pageNumber=1&virtualBrandChannel=0>.
- [3] C. Mbohwa, "Operating A Railway System Within A Challenging Environment: Economic History And Experiences Of Zimbabwe's National Railways", *Journal Of Transport And Supply Chain Management* | November 2008, Pp 25-40
- [4] Zimbabwe GDP real growth rate, [http://www.indexmundi.com/zimbabwe/gdp\\_real\\_growth\\_rate.html](http://www.indexmundi.com/zimbabwe/gdp_real_growth_rate.html) (accessed 07-08-12)
- [5] <http://www.equityzw.com/2-Understanding-Energy-Security.html>
- [6] C. Mbohwa, "Assessment of Electricity and what needs to be done", *The Electricity Journal*, August / September 2002, pp 82-91
- [7] Coal Statistics for South Africa, Botswana, Mozambique, Zimbabwe and Namibia between 2006 and 2010, (<http://coal-stats.realclearworld.com/compare/7-35-63-77-133/South-Africa-vs-Botswana-vs-Mozambique-vs-Zimbabwe-vs-Namibia>) (Accessed 01-01-13)
- [8] D. Todd and J. Fengjun, "Interregional coal flows in China and the problem of transport bottlenecks: Upholding the rail option", *Applied Geography*, vol. 17, no 3, pp 215-230, 1997
- [9] B Bilgen, "Modelling of a blending and marine transportation planning problem with fuzzy mixed integer programming," *International Journal Adv Manufacturing Technology*, 2008, vol. 36: pp. 1041-1050
- [10] Mc Collum and Ogden, "Future impacts of Coal distribution constraints on coal costs, *Transportation Research Part E* 45 (2009) 460-471.
- [11] V. A. Brodskii, "Balance of Supply and Demand in the Russian Market for Coking-Coal Concentrates", *Coke and Chemistry*, vol. 53, No 11 pp 416-427, 2010
- [12] D. Fang, M. Zhang, and X. Wang "Power Coal transportation and Storage: A programming Analysis of Road and Rail options", *Wuhan University Journal of Natural Sciences*, vol 16, No 6, 469-474, 2011
- [13] D. Mou, , Z. Li, "A spatial analysis of China's coal flow. *Energy Policy*", (2012), <http://dx.doi.org/10.1016/j.enpol.2012.05.034>
- [14] J. H. Havenga, "Rail renaissance based on strategic market segmentation principles", *Southern African Business Review*, 16(1), 2012
- [15] MOEPD, "National Energy Policy", Ministry of Energy and Power Development, Republic of Zimbabwe, 2012
- [16] La Londe, J. Bernard and J. M. Masters, "Emerging Logistics Strategies: Blueprints for the Next Century," *International Journal of Physical Distribution and Logistics Management*, Vol. 24, No. 7, pp. 35-47, 1994
- [17] R Monczka, R Trent, and R B Handfield "Purchasing and Supply Chain Management, Cincinnati, OH: South-Western College Publishing, Chapter 8, 1998
- [18] J.T. Mentzer, W. DeWitt, Keebler, S. Min, N.W. Nix, C.D. Smith, and Z.G. Zacharia, "Defining Supplychain Management, *Journal Of Business Logistics*", Vol. 22, No. 2, 2001, pp 1-25