A LIFE CYCLE COST ANALYSIS OF THE GAUTENG TO DURBAN FREIGHT CORRIDOR: INITIAL ROAD CORRIDOR INFRASTRUCTURE COSTING

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ABSTRACT

Numerous studies have been undertaken both locally and internationally to ascertain the most cost effective and beneficial form of freight transport, but in a number of instances these studies ignore certain basic externalities that require consideration and analysis to provide a meaningful and representative outcome. Only once all significant costs have been fully internalised can the performance of freight transport be accurately computed and investment in freight transport infrastructure satisfactorily justified.

The paper firstly briefly reviews the progress with respect to the Gauteng to Durban Freight Study. The aim of the paper is to review the elements constituting the infrastructure costs of both the rail and road freight transport modes and to provide a comprehensive assessment of the current road infrastructure costs along the Gauteng to Durban Freight Corridor.

The paper provides a comprehensive quantification of infrastructure costs of the road freight corridor extending from Gauteng to Durban utilising current construction costs for the estimate of the replacement value of the road network to a predefined condition. The analysis compares the comparative costs of the various infrastructure components on the road corridor and draws conclusions as to the effect of infrastructure costing on total life cycle costing along the Gauteng to Durban Freight Corridor with respect to road freight transport cost. It will furthermore discuss the freight capacity of the road transport mode in relation to its replacement costs and the capability of the existing infrastructure in fulfilling its predicted freight transport role.

1. INTRODUCTION

1.1 Freight Transport in South Africa

Freight transport in South Africa is dominated by two modes, namely road transport and rail transport. Significant discussions and hypotheses have been put forward as to the demise of rail freight transport in the face of ever increasing road freight transport. This increase in road freight transport is not merely linked to highly perishable goods, but is increasingly extending to “low value” bulk commodities such as coal and iron ore.

The rail system has been described as being in “a near state of collapse” due to enormous under investment since road replaced rail as the dominant freight transport mode from the mid 1980s. The ever increasing road freight transport is also taking its toll on the current road network and is not contained only within the corridors and national and provincial routes, but is extending to the rural road network, never designed to withstand such loading conditions

1.2 Gauteng to Durban Freight Corridor Study

1.2.1 Background to study

The study was originally initiated through discussions between the Rail/Road Association (RRA) and the University of Pretoria’s Chairs in Transport Engineering and Railway Engineering to focus on the actual costs of road and rail freight transport within South Africa taking into consideration externalities such as environmental, safety and cross subsidisation. Originally packaged as a Doctoral Study of limited scope, a preliminary scope of works for the study was drawn up at which time the extent of the study was re-evaluated to focus on the Gauteng to Durban Freight Corridor and expanded to include additional research capacity through the inclusion of post-graduate assistance and aligned research initiatives.

Through a number of subsequent discussions with the RRA, the Department of Transport, Spoornet and the Road Freight Association the study goals, activities and proposed deliverables were contextualised and refined to their current state.

1.2.2 Goals and objectives of study

The primary goal of the research project is to evaluate through a holistic systems approach the total costs of the primary modes (road and rail) of freight transport in South Africa, taking into account all internal and external costs associated with such modes of freight transport.

A secondary related goal is to quantify each mode’s respective roles in providing the most cost effective and efficient freight transport system to the country as a whole. At present the study is primarily focussed on the investigation of the actual costs of rail and road freight transport. Additional transport modes, such as air, maritime or pipeline, carrying significant freight transport will be included in the study as it progresses.

1.3 Infrastructure costs of rail and road corridors

Various studies have been undertaken concerning the provision of transport infrastructure, with a plethora of definitions utilised to identify infrastructure costs. In certain instances the costs of rolling stock for rail transport are included while maintenance, either routine or periodic, have been included by authors as infrastructure costs in their respective papers.

For the purpose of this paper infrastructure cost is defined as the cost relating to the construction of the travelled way, to a set standard, utilised for the transport of persons,

goods and materials, excluding the costs relating to the human management of the travelled way and not taking into consideration the costs relating to maintenance of the way.

It should furthermore be noted that the infrastructure costs described within this paper represent replacement costs to the specific level of serviceability and life expectancy. Infrastructure costs are significantly affected by the methodology implemented for the maintenance of the infrastructure asset, with this relationship generally being inversely proportional (high initial infrastructure cost generally requires lower maintenance costs and vice versa).

1.4 Aim of paper

The paper firstly briefly reviews the progress with respect to the Gauteng to Durban Freight Study. The aim of the paper is to review the elements constituting the infrastructure costs of both the rail and road freight transport modes and to provide a comprehensive assessment of the current road infrastructure costs along the Gauteng to Durban Freight Corridor.

1.5 Scope of paper

The scope of the paper encompasses the following:

- Overview of the current progress of the study;
- Identification of the various components contributing the infrastructure costs of rail and road corridors;
- Comprehensive quantification of infrastructure costs of the road corridor extending from Gauteng to Durban;
- Comparison of the costs of various infrastructure components; and
- Analysis of the replacement costs of the road corridor based on capacity of the corridor.

2. GAUTENG TO DURBAN FREIGHT CORRIDOR STUDY – CURRENT PROGRESS

2.1 Study Tasks

The study tasks are illustrated schematically in Figure 1. This list is not all encompassing but should be viewed as a proposed set of tasks and related objectives for further discussion with role players and incorporation within the scope if deemed pertinent. Although these tasks are being undertaken as separate entities of research, the authors are fully aware of the mutual interdependency of certain of the tasks, and therefore a review and collaboration task has been included prior to the life cycle cost analysis to ensure that these interrelationships are adequately defined and that the findings of each task are accurate and relevant.

2.2 Study Progress

Accurate information and the collation of this information form the basis for the entire research project. A number of discussions have been held with various stakeholders over the past year. Due to the sensitive nature of the research project and the competitive nature of the various modes, care needed to be exercised to ensure that all parties were satisfied that the information supplied would be used in an appropriate manner.

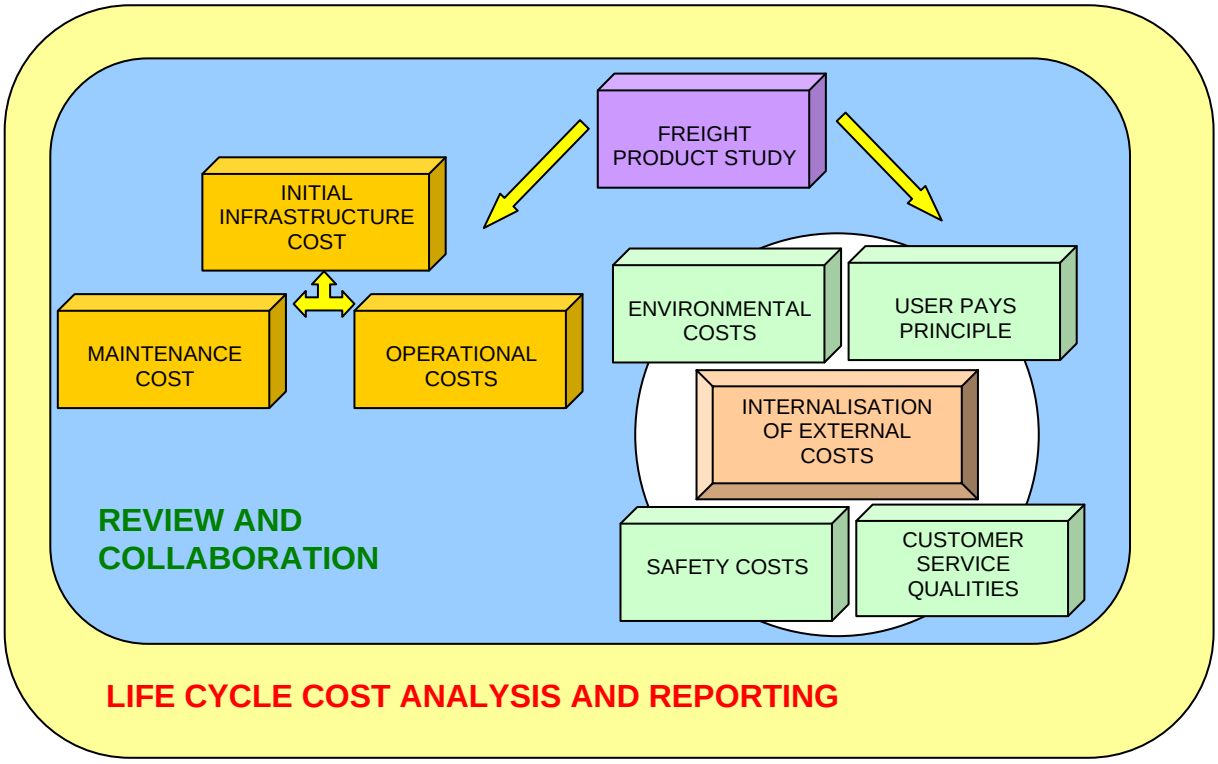

Figure 1: Schematic representation of study tasks

These discussions have been completed with Spoornet and with the N3 Toll Company which have both agreed to the provision of information as requested. Buy-in has also been obtained from the National Department of Transport, the Gauteng Department of Public Transport, Roads and Works, the Free State Department of Transport and the South African National Roads Agency regarding possible information, which is valuable to the project.

The overall project progress to date, based on the proposed research project programme, is approximately 35%. This is based on taking into consideration the estimated progress of each sub activity and extrapolating the progress based on the time requirements for the various project sub activities.

Due to the delay of certain activities primarily a result of the lack of required information for analysis, a number of tasks and sub activities planned for late 2007 have already been initiated in order to ensure that the overall progress is maintained. To date this has been successfully undertaken. However, the data requirements have reached a crucial stage. The information requirements have been discussed extensively with the relevant stakeholders and assurances have been made that the information will be made available shortly. It is still anticipated that the study can be completed within the proposed 3-year period, with draft reporting available by end 2008.

3. INFRASTRUCTURE COSTS OVERVIEW

3.1 Introduction

Initial infrastructure cost plays a significant, if not the primary, role in the cost analysis of various transport alternatives and should provide an accurate estimate of the replacement construction cost of the existing infrastructure along both the road and the rail transport corridors in present day Rand value. Primary factors considered include land use cost, basic cost of rail infrastructure and basic cost of road infrastructure. The costs relating to

the port terminal and associated infrastructure requirements will also be taken into consideration on a tonnage basis for each mode.

3.2 Basic infrastructure

The Gauteng to Durban Freight Corridor is defined as the corridor extending from central Johannesburg, in the vicinity of Newtown, to the port in Durban. The road corridor extends over a distance of approximately 580 km dependent on the route taken within the Johannesburg region. The geometric layout of the corridor consists generally of a 4-lane dual or single carriageway road consisting of flexible and rigid pavement sections. In certain areas the road consists of 6 lanes incorporating additional slow climbing lanes and crawler truck traffic lanes in the vicinity of Pietermaritzburg and Durban.

The Gauteng to Durban rail corridor extends over a distance of 688 km and deviates significantly from the road corridor via Volksrust, Newcastle and Ladysmith. The corridor consists of a double line over its entire length with numerous branch lines.

3.3 Components contributing the infrastructure costs of the rail and road corridors

As stated in Section 1.2 of this paper infrastructure cost is defined as the cost relating to the construction of the travelled way (the asset), to a set standard, utilised for the transport of persons, goods and materials, excluding the costs relating to the human management of the asset and not taking into consideration the costs relating to maintenance of the asset.

3.3.1 Road infrastructure components

Road infrastructure cost components can generally be classified into four distinct categories namely:

- General roadwork's cost;
- Bridge's and culvert's cost;
- Land cost; and
- Contractual cost.

The first three categories are self-explanatory. Contractual cost is a broad category including the costs relating to the design of the infrastructure and the management of its construction. Generally these costs are indicated as a percentage of the actual construction costs.

A further infrastructure cost indirectly linked to road construction, but which forms a major asset investment in terms of the Gauteng to Durban Road Corridor, is the toll road specific infrastructure such as the toll gates and emergency facilities and services found on toll roads throughout South Africa. Although not a "pure" infrastructure cost the asset is essential to ensure the condition of the travelled way through the provision of funding for the maintenance, rehabilitation, upgrading and general management of 75% of the length of the road corridor. Toll roads provide the revenue required for their continued existence and thus the infrastructure costs relating to toll operations needs to be accounted for in the infrastructure costing model.

The subsequent sections of this paper will present a comprehensive analysis of the infrastructure costs of the road corridor.

3.3.2 Rail infrastructure components

Rail infrastructure consists of a larger number of infrastructure cost components compared to the road corridor. These additional cost components are primarily a result of the

necessity of the rail infrastructure to provide essential control of the movement of trains along the track and to provide propulsion effort to the trains via electricity. The cost components of the rail corridor can be summarised as follows (Ott, 2002):

- Superstructure and substructure cost;
- Special buildings (bridges and tunnels) cost;
- Land cost;
- Signalling cost;
- Electrification cost; and
- Telecommunications cost.

4. ROAD CORRIDOR INFRASTRUCTURE COST

4.1 Cost calculation methodology, principles and assumptions

The calculation of the infrastructure cost of the Gauteng to Durban Road corridor is based on the quantification of the cost of the construction of new 4-lane dual and single carriageways along the existing alignment. The cost (commonly referred to as replacement value) is based on 2006 base year construction rates for proposed new construction of similar corridors within South Africa based on the information included in the Table 1.

It should be noted that the construction cost rates utilised for the analysis of the infrastructure costs for the Durban to Gauteng Road Corridor is based on the construction of a dual/single carriageway in a rural environment. Thus extrapolation is necessary to predict the actual infrastructure cost of the road corridor in areas where it traverses an urban environment such as the section south of Johannesburg and the section between Pietermaritzburg and Durban.

The analysis will firstly present the infrastructure cost related to the current alignment and capacity of the N3 Toll Road. This analysis will form the basis for the estimation of the infrastructure cost of the entire Gauteng to Durban Road Corridor.

Table 1: Infrastructure cost basic principles and assumptions

Property	Basic principle/ Assumption
Terrain	▪ Mountainous, winding, sharp curves ▪ Hilly, winding ▪ Rolling, long straight with short sharp curves ▪ Rolling, long straight with sharp curves ▪ Rolling and winding long curves ▪ Rolling with long straights Fairly straight and gentle curves ▪ Long straights and gentle curves
Geometry	4-lane dual/single carriageway
Design life	25 years (excluding structures)
Design loading	35 million E80’s in slow lane

4.2 N3 Toll Road infrastructure cost

The N3 Toll Road consists of both single and dual carriageway road sections, predominantly with a 4-lane configuration. The N3 Toll Road is 415 km in length, representing approximately 75% of the total length of the Gauteng to Durban Road Corridor, extending from Heidelberg in the North to Cedara in the South. Table 2 provides a summary of the infrastructure of the N3 Toll Road

Table 2: Summary of N3 Toll Road infrastructure

Elements	Number/Length
Single Carriageway	205.6
Dual Carriageway	209.7
Flexible pavement	326.3 km
Rigid pavement	89 km
Bridges	136
Interchanges	26
Retaining structures	3
Climbing Lanes	6 lane km's
Mainline toll plazas	4
Ramp toll plazas	3

4.2.1 General roadwork's cost

Utilising 2006 as a base year the general roadwork's cost of each km of the N3 Toll Road as per the specifications shown in Table 1 varies from R15 million to R25 million dependent on the terrain being traversed and geometry of the road section. Figure 4 provides a detailed breakdown of one of the various terrain and geometric conditions modelled, indicating the major components/activities of the construction.

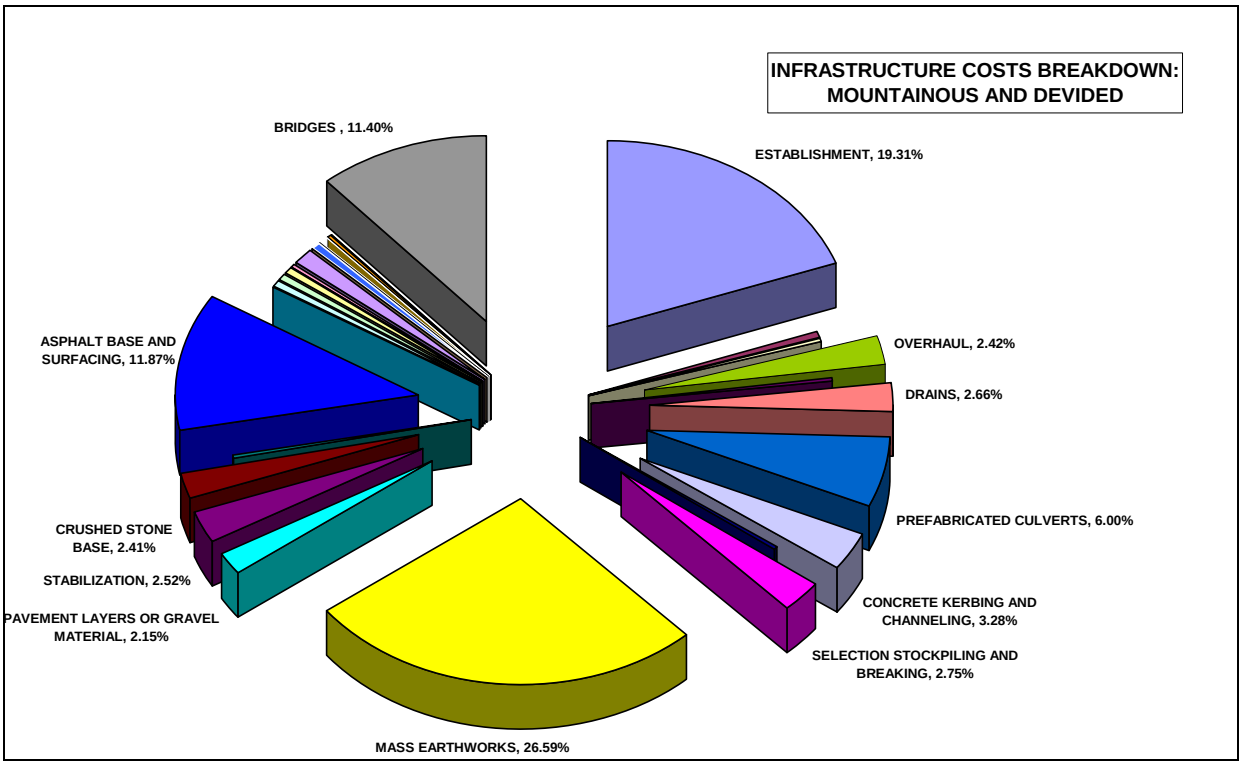

Figure 2: Breakdown of roadwork's construction cost (dual carriageway, mountainous terrain)

Figure 2 includes only the construction costs and does not take into account the Consultancy design and supervision fees, risks, CPA and Contractor's profit. These cost items will be taken into account on a percentage of construction cost basis in the subsequent sections of this report.

The major activities are represented, in order of magnitude as the following:

- Mass earthworks;
- Contractors establishment and 'Preliminaries and Generals';
- Asphalt Base and Surfacing; and
- Bridges and major drainage structures

Bridges represent a major proportion of the costing exercise represented in Figure 2. This costing exercise is based on a 75 km section of road. One can appreciate that the number of bridges constructed over a section of road can vary significantly. Figure 3 indicates the average number of road kilometres between each bridge structure on the N3 Toll Road. Thus the cost of bridge construction was estimated separately for the total cost calculation and summed to the general road construction cost for the estimation of the total construction cost.

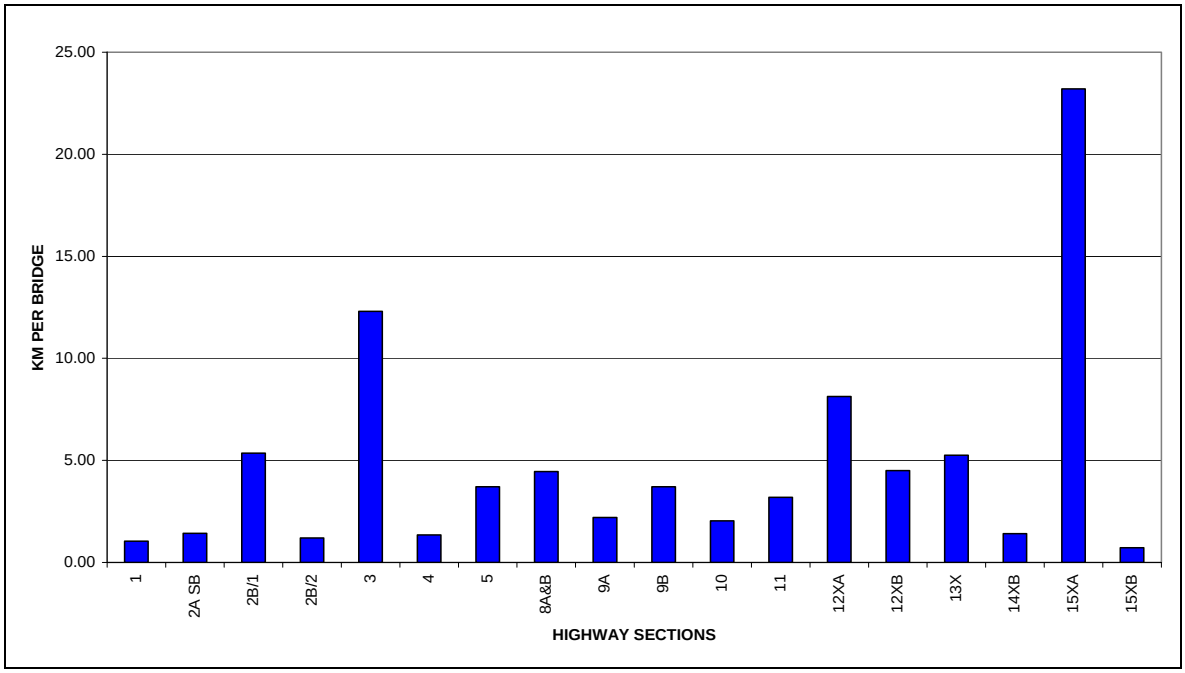

Figure 3: Average number of km of road between bridges on various sections of the N3 Toll Road

4.2.2 Variation in road construction cost based on geometry and terrain

Geometric requirements and terrain are inter-related in terms of the cost of construction. The general trend is increased infrastructure provision cost in areas described as difficult or mountainous terrain, which in turn require more stringent geometric requirements.

Figure 4 provides a comparative breakdown of the road construction cost contributions for the various activities between a meandering undivided, single carriageway 4-lane road and a divided, dual carriageway 4-lane road. Although the activities provide a good trend with regards to the percentage contribution to the construction cost, the value of construction for a 4-lane dual carriageway road in mountainous terrain is approximately 1.8 times that of the cost related to construction of a 4-lane single carriageway road in meandering or flat terrain.

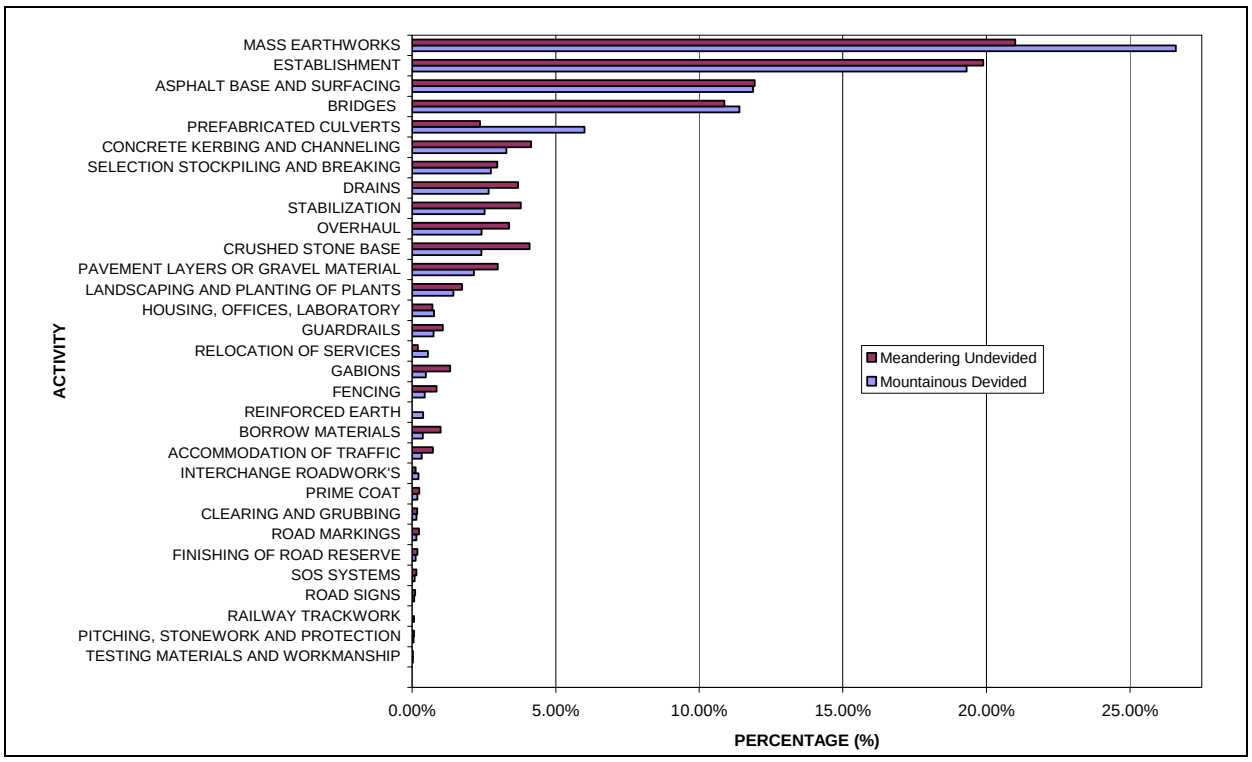

Figure 4: Comparison of roadwork's construction cost for varying road construction terrain

4.2.3 Land Cost Estimation

The land cost estimation is based on the cost paid for land in the various provinces in South Africa undertaken through the land restitution processes. This process is based on the "willing-buyer/willing-seller" principle. The values paid for the purchase of land represented in Figure 5 vary significantly. The predominant factors in this variation are the following:

- Current land usage and location – agricultural, subsistence versus urban, industrial;
- Mineral rights; and
- Sizes of properties purchased.

From Figure 5 it is evident that the value of land along the Gauteng to Durban Freight Corridor varies from as high as R8 750/hectare in Gauteng to as little as R265/hectare in the Free State. Note that in certain circumstances, state owned land formed a portion of the property sold. This explains to a degree the significant variations between Gauteng (which possesses the least freely tradable land) and provinces such as the Free State. Taking inflationary trends in the property market into account the 2006 value of property along the corridor could be 15 – 20% higher in 2006 monetary terms than the figures indicated in Figure 5.

For the purposes of this paper the following land prices are estimated for each of the four provinces traversed by the corridor:

- Gauteng Province - R 10 000/hectare
- Mpumalanga Province - R 650/hectare
- Free State Province - R 400/hectare
- Kwazulu Natal Province - R1 500/hectare

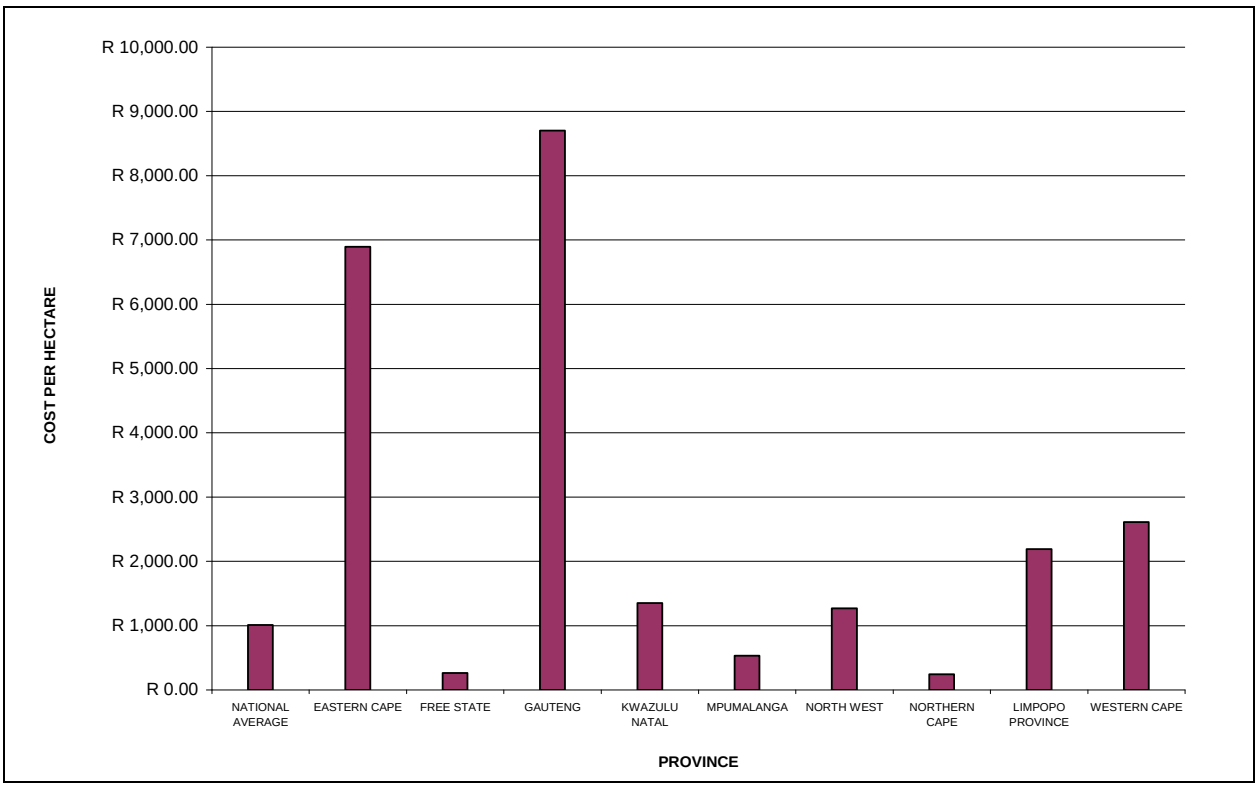

Figure 5: Land restitution average costs paid per province (Dept. of Land Affairs, 2003)

In order to accommodate the Gauteng to Durban Road Corridor the road reserve would be required to accommodate a dual carriageway six-lane road with shoulders and a sufficient median. Ignoring the land requirements for toll plazas and associated operations and interchanges a road reserve in the order of 80 to 100 m in width is required. Taking the 100 m width as a basis and utilising the values estimated for the land costs in each province the theoretical cost related to land for the construction of a Gauteng to Durban road corridor is approximately R10.4 million.

This analysis however represents the costs related to acquiring land based for settlement purposes and does not take into consideration the premium payable for the purchase of a strip of land extending 555 km from Gauteng to Durban. The cost of such a purchase could well amount to a value 1 factor (10x) greater than the restitution purchase costs. For the purposes of this infrastructure analysis a land cost of R100 million is utilised in the calculations.

4.3 Estimated Infrastructure Cost of Gauteng to Durban Freight Corridor

Taking into consideration the infrastructure cost derived for the N3 Toll Road and extrapolating this value over the entire length of the road corridor the infrastructure cost of the Gauteng to Durban Road Corridor can be estimated. This method of quantification assumes a standard pavement structure and load carrying capability over the entire length of the corridor and is not representative of the actual pavement structures that vary between flexible and rigid pavement structures.

The infrastructure cost of the Gauteng to Durban Road Corridor is summarised in Table 3 below. Certain values have not been extrapolated over the entire length of the corridor as indicated.

Table 3. Summary of Durban to Gauteng road corridor infrastructure cost

Cost Components	Value R mil (2006 Base year)
General roadworks	R 10 179.834
Bridges and culverts	R 1 963.366
Land cost	R 100.000
Interchanges	R 869.290
Retaining structures	R 80.242
Mainline toll plazas*	R 325.000
Ramp toll plazas*	R 100.000
Contractual	R 2 433.192
Total (516 km)	**R 16 050.927**

* not extrapolated over Gauteng non-toll section

5. COMPARISON OF ROAD INFRASTRUCTURE COST

Significant uncertainty exists as to the actual construction cost of dual and single carriageway 4-lane high level roads. This can be predominantly attributed to the following factors:

- Varying design standards;
- Variation in traffic, and traffic loading distributions;
- Varying pavement design methodologies;
- Variation in base costs of materials and labour; and
- Varying level of service and categorisation discrepancies.

Figure 6 illustrates this variation between infrastructure and other road construction and maintenance costs. Figure 6 is based on a study by Archondo-Callao (World Bank, 2004) of 93 World Bank projects in 40 Countries between 1990 and 1995, adjusted for inflation and exchange rate.

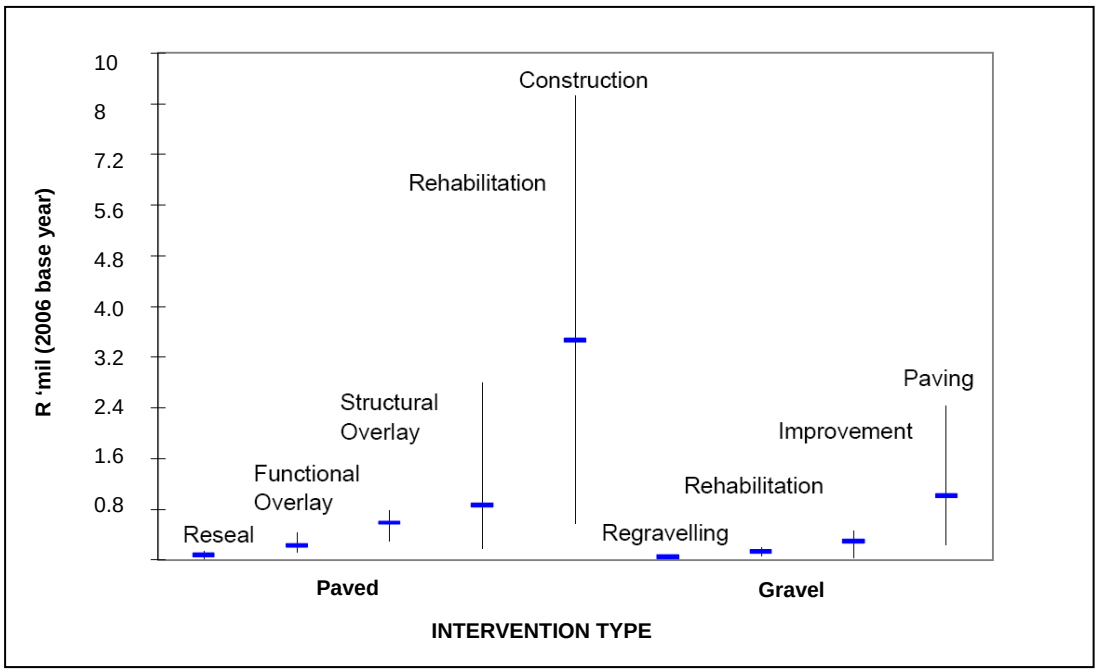

Figure 6: Average and median cost on infrastructure provision and maintenance - (2006 Base Year Rand) (World Bank, 2004)

Table 4 provides a comparison between the lane-km cost of the Gauteng to Durban Road Corridor and various road project costs, or average construction costs in various countries. The figures have been adjusted for currency and inflation. Note that only the Gauteng to Durban Road Corridor takes account of all structures along the route as well as the value of land. Analysing the data in Table 4 it is evident that the infrastructure cost of the Gauteng to Durban Road Corridor compares favourably with the national average values, particularly considering the level of service variation within our national road network.

Table 4 furthermore provides good correlation between figures indicated by other researchers. Notwithstanding the figures presented in Table 4, numerous researchers (Beeld,2006) have indicated that the replacement value of the Gauteng to Durban Road Corridor would cost approximately R8 -12 billion or R3.6 - 5.4 million per lane km . This estimate compares vary favourably with the average cost of national roads in South Africa (R 4.9 million per lane km), but is half to two thirds of the actual replacement value of the Gauteng to Durban Freight Corridor.

Table 4: Comparison of infrastructure cost (2006 Base Year Rand)

Country/ Province	Road Type/ Configuration	Value R /lane-km (2006 Base year)	Reference
USA, Wisconsin (Project)	County Road	R 1 054 000	(Clark County, 2003)
South Africa (Average)	National	R 4 894 000	(AA, 2003)
	Provincial	R 776 000	
	Local Roads	R 815 000.	
Portugal (Average)	6-lane motorway	R 3 476 000	(Terra Mileniul, 2004)
United Kingdom	6-lane motorway	R 6 502 000	
GAUTENG TO DURBAN CORRIDOR	**4-lane dual and single carriageway**	**R 7 225 000**	
Canada, British Columbia (Average)	2-lane highway	R 7 840 000	(British Columbia, 2004)
	4-lane highway	R 11 760 000.	
Greece	6-lane motorway	R 8 814 000	(Terra Mileniul,2004)
Romania (Project)	Motorway - Romania	R 13 470 000	

6. ANALYSIS OF ROAD INFRASTRUCTURE COST IN RELATION TO FREIGHT TRAFFIC

The infrastructure cost of the Gauteng to Durban Road Corridor can be analysed in terms of the freight hauled along the corridor. In order to perform such an analysis the expected traffic levels are required for the design life of the pavement.

The N3 Toll Road traffic predictions for the period 2006 to 2029 are utilised as the basis for traffic information (N3TC, 2006). Based on these figures the predicted cumulative E80.km for the 23 year period equates to 108 300 Million E80.km over the entire length of the corridor.

This equates to a value of R 0.148/E80.km or R275/one directional trip for a freight haulier with a Gross Vehicle Mass equivalent to the average E80/HV of 3.5 (28 tonnes). Note that

this figure takes into consideration the cost of providing the infrastructure only and does not include the reconstruction, rehabilitation and routine road maintenance cost as well as the operational costs required to maintain the infrastructure over the design period of the road, in this case a period of approximately 25 years (23 years Concession and approximately 2 years remaining life). Required capacity upgrades are accounted for in the maintenance costing. Maintenance and operational costs as well as externalities such as environmental costs (noise and pollution), congestion costs and accident costs need to be quantified prior to the actual cost of freight transport by road being adequately quantified.

The infrastructure cost presented in this paper is based on the provision of a pavement with a structural capacity of 35 million E80s. The current freight capacity utilisation of the N3 Toll Road under its current geometric configuration is estimated at 40 to 50% (Morton et al, 2006). Currently the lowest cumulative traffic estimated over any section of the pavement equates to approximately 35 million E80s. Thus the initial infrastructure cost quantification represented in this paper provides sufficient structural capacity over the proposed design life for the road section experiencing the lightest current loading

Additional structural capacity is provided to the highly trafficked road sections through periodic rehabilitation reconstruction and capacity upgrades. Considering that the highest trafficked section of the corridor is expected to carry a cumulative (per carriageway) 148 million E80, over the next 25 years, it is foreseeable that the maintenance and rehabilitation costs related to maintaining the pavement structure and providing additional structural capacity during the pavement design life will be significant. This is evident in the quantification of the maintenance costs along the corridor presented in a separate paper.

7. CONCLUSIONS

The overall project progress to date, based on the proposed research project programme, is approximately 35%. The project finalisation date is estimated as last quarter of 2008 first quarter of 2009, subject to the availability of information related to the rail corridor.

The infrastructure cost presented in this paper is defined as the cost relating to the construction of the travelled way (the asset), to a set standard, utilised for the transport of persons, goods and materials, excluding the costs relating to the human management of the asset and not taking into consideration the costs relating to maintenance of the asset.

Road infrastructure cost components can generally be classified into four distinct categories of general roadworks; bridges and structures; land costs; and contractual costs.

The infrastructure cost quantification is based upon actual priced road construction works computed for various terrains and extrapolated over defined sections of the existing corridor route.

The infrastructure cost presented in this paper is based on the provision of a pavement with a structural capacity of 35 million E80s. The current road infrastructure cost of the Gauteng to Durban Road Corridor is quantified at R 16.050 billion in 2006 monetary value.

The infrastructure provision cost per E80.km is on the Gauteng to Durban Road corridor is R 0.148/E80.km or R275/one directional trip for a freight haulier with a Gross Vehicle Mass equivalent to the average E80/HV of 3.5 (28 tonnes). Note that this is only part of the road provision cost and should not be used as an argument for the reduction or increasing of tolls for trucks in isolation of other cost components.

8. ACKNOWLEDGMENTS

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