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

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ABSTRACT

Freight transport in South Africa is dominated by two modes, namely road transport and rail transport. The current dominance of road is not only linked to high value commodities, perishables or short transport distances, but has recently been extended to include freight transport of bulk low value goods such as coal and iron ore, previously the domain of rail transport. The condition of the rural road network is deteriorating rapidly as traffic volumes and axle loads increase on an aging network.

The paper firstly briefly reviews the progress with respect to the Gauteng to Durban Freight Study. The aim of the paper is to provide an assessment of the maintenance costs associated with the current road infrastructure along the Gauteng to Durban Freight Corridor for the next two decades.

The paper provides a comprehensive quantification of maintenance cost requirements of the road freight corridor extending from Gauteng to Durban. The analysis takes into consideration both routine maintenance and periodic maintenance, reconstruction upgrading requirements associated with the current freight conditions and the prospective maximum freight utilisation along the route based on current trends in traffic loading measured over the past 5 years.

The analysis will compare the comparative costs of various forms of maintenance and rehabilitation, reconstruction and upgrading tasks proposed for the road corridor. It will provides insight into the maintenance requirements of the current infrastructure, the success of the current maintenance investment in preserving the assets and the expected result of increased freight transport and loading on the maintenance requirements under full capacity freight loading conditions.

1. INTRODUCTION

1.1 Current Freight Network

The primary road network is in most instances completed, with maintenance, rehabilitation and reconstruction taking precedence over capacity enhancements. Current maintenance investments are insufficient, particularly with regards to the minor rural and provincial roads, to provide adequate structural capacity in combination with preservation of current structural integrity in response to increasing traffic and higher loading conditions.

The rail system has been described as being in “a near state of collapse” due to enormous underinvestment. Current rail associated interest is placed on the financing and investment in new rolling stock and the upgrading of major lines, while maintenance requirements are seen as secondary in importance.

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 maritime, air and pipe transport, carrying significant freight will be incorporated into the study as it progresses.

1.3 Maintenance costs of rail and road corridors

Maintenance costs of road infrastructure have been keenly debated for a number of decades following the construction of the base road network in South Africa. In the provision of a road network, the maintenance of roads is as important as their construction. Without proper maintenance, roads deteriorate rapidly and reconstruction becomes necessary prematurely (NRA, 2001).

Significant uncertainty exists as to the optimal expenditure on road maintenance in order to minimize total life cycle cost of transport. Generally the cost of inadequate maintenance results in significant expenditure requirements for major reconstruction, which is ultimately

borne by the road user. In addition to the cost of increased taxation and toll fees, the cost of inadequate road maintenance is borne by the road user in terms of the vehicle operating costs. A reduction of R1 in maintenance can result in a vehicle operating cost increase of up to R3 (Chand Ecosense, 2003).

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 all forms of maintenance currently applied to the road corridor and present a comprehensive analysis of the maintenance cost related to the provision of the Gauteng to Durban Road Corridor over a 25 year design life period.

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 forms of maintenance contributing to the overall maintenance of the road corridor;
- Comprehensive quantification of maintenance costs of the road corridor extending from Gauteng to Durban;
- Comparison of the costs of various maintenance actions components; and
- Analysis of the maintenance costs of the road corridor based on capacity of the road 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.

These discussions have been completed with Spoornet and with the N3Toll 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 that is valuable to the project.

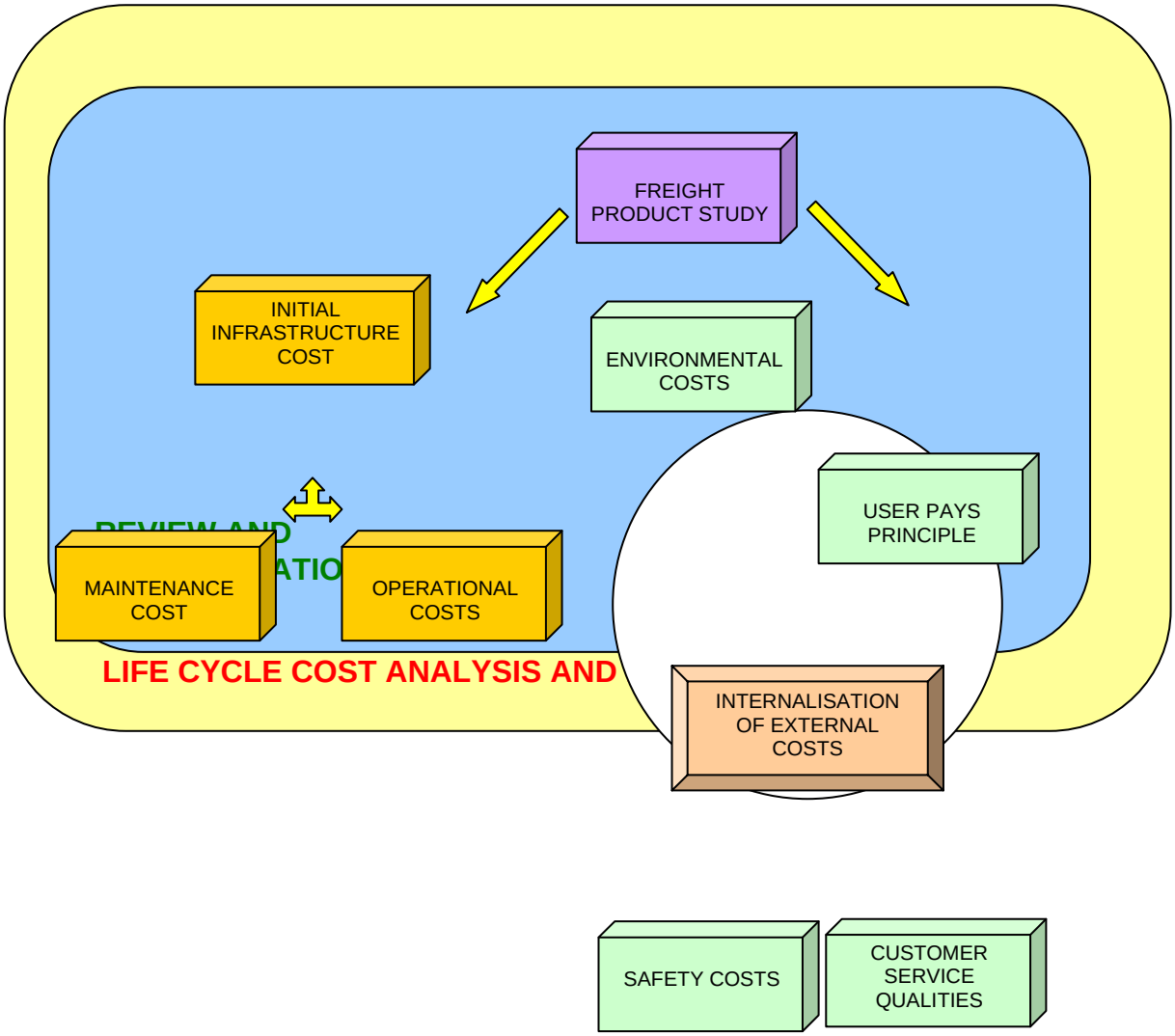

Figure 1. Schematic representation of study tasks

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 as 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. MAINTENANCE COSTS OVERVIEW

3.1 Introduction

Maintenance costs play a significant role in the cost analysis of various transport alternatives. The maintenance cost strategy is directly dependent on the infrastructure provision methodology adopted by the designers. Higher initial infrastructure cost is generally offset over the lifetime of the infrastructure by a lower maintenance cost and vice versa. A large proportion of the maintenance cost is indirectly proportional to the initial construction costs for a limited design period. Environmental factors will ultimately require maintenance activities to be instituted along a road irrespective of the initial construction cost and the structural carrying capacity designed for. In the case of the Durban to Gauteng Road Corridor the current pavement structure can be classified as a high traffic level design (ES100) with an average structural capacity of 30 to 40 million E80s.

3.2 Various forms of maintenance

Three primary forms of maintenance can be categorised for the Gauteng to Durban Road Corridor and the higher level road network throughout South Africa. These can be defined as follows:

- Routine road maintenance activities;
- Periodic maintenance activities; and
- Structural rehabilitation, reconstruction, upgrading and capacity improvements.

3.2.1 Routine road maintenance

Routine road maintenance can be defined as the routine activities required in order to maintain the travelled way in an acceptable condition to the road user and ensuring that the various components of the infrastructure are functioning in a proper manner. By definition these activities are short term, reactive operations applied all year round and will include emergency repairs of limited nature to the pavement structure.

Routine road maintenance includes the following primary activities:

- Surface patching of roads;
- Cleaning of concrete drains and channels;
- Fencing;
- Collection and removal of debris and litter;
- Guardrail erection and maintenance;
- Controlling vegetation growth: Mowing and cutting; and
- Removal of undesirable vegetation: Physical eradication.

3.2.2 Periodic maintenance

Periodic maintenance can be defined as all actions and activities undertaken on the infrastructure, primarily the pavement structure, bridges and the associated drainage, in order to improve the functional quality of the pavement and inhibit the rate of deterioration of the pavement under trafficking and environmental conditions, thus extending the structural life of the pavement. Periodic maintenance includes the following primary activities:

- Drainage repairs;
- Crack sealing;
- Resealing of roads with fog sprays, seals, slurries and rejuvenators;
- Patch repairs to potholes and limited areas of structural failure; and
- Thin asphalt overlays (up to 40 mm).

3.2.3 Structural rehabilitation, upgrading and capacity improvements

Structural rehabilitation, upgrading and capacity improvements include all activities primarily aimed at improving the structural capacity of the pavement, through various methods, and the provision of additional lanes to provide for an improved level of service. The differentiation between periodic maintenance and rehabilitation is not precise, since in periodic maintenance works a certain degree of structural improvement, however limited, is usually undertaken. Similarly surface seals are used extensively during structural upgrading and rehabilitation to meet functional performance criteria. Structural rehabilitation and upgrading is however generally undertaken on a large scale to repair a general structural inadequacy within a section of pavement usually in excess of 30 km in length.

The major differentiating factor between periodic maintenance and structural rehabilitation and upgrading is that periodic maintenance excludes geometric improvements to the road prism, while structural rehabilitation and upgrading can include geometric improvements if required. Primary activities undertaken under structural rehabilitation, reconstruction and upgrading include the following:

- Reconstruction of existing pavement layers through recycling and stabilisation;
- Construction of new base layers, granular or otherwise, including subbase repairs if required;
- Provision of asphalt overlays (>40 mm);
- Widening of shoulders; and
- Construction of climbing lanes.

4. ROAD CORRIDOR MAINTENANCE COST

4.1 Cost calculation methodology, principles and assumptions

The calculation of the maintenance cost of the Gauteng to Durban Road Corridor is based on quantifying the maintenance costs of a 4-lane dual and single carriageway road over a design period of 25 years. The cost is based on 2006 base year construction rates for proposed maintenance actions and is based on the assumptions included in Table 1 below.

Table 1. Maintenance cost basic principles and assumptions

Property	Basic principle/ Assumption
Existing pavement structural capacity	Varies depending on pavement structure and estimated traffic. Average pavement structural capacity of >25 million E80s
Geometry	4-lane dual or single carriageway
Design life	25 years (excluding structures)
Environmental	Varying from arid to high rainfall, highveld to coastal conditions
Design loading	Varies over pavement sections from 35 million E80's to > 120 Million E80s in slow lanes

It should be noted that the maintenance cost computed is based on a modelled pavement maintenance and structural upgrading strategy, which is dependent on a number of factors and includes a significant degree of uncertainty. However, assuming that traffic loading and environmental conditions remain consistent as predicted, the quantum of the routine maintenance, periodic maintenance, rehabilitation and upgrading works proposed should provide a fair reflection of the costs involved with maintaining the Gauteng to Durban Road Corridor. The maintenance costing is based on the predicted expenditure of the updated road strategy for the N3 Toll Road, and has been extrapolated over the entire length of the Gauteng to Durban Road Corridor, taking into consideration the anticipated traffic loading and environmental conditions of each pavement section.

4.2 N3 Toll Road maintenance 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. 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 km
Dual Carriageway	209.7 km
Flexible pavement	326.3 km
Rigid pavement	89 km
Bridges	136
Interchanges	26
Retaining structures	3
Climbing Lanes	6 lane km
Mainline toll plazas	4
Ramp toll plazas	3

4.2.1 Routine road maintenance cost

Utilising 2006 as a base year the routine road maintenance cost for the N3 Toll Road can be quantified based on the actual expenditure of the 12-month period from January 2006 to December 2006. Figure 2 provides a breakdown of the proportional expenditure on each of the activities undertaken as part of the routine road maintenance on the N3 Toll Road.

Thirty separate activities are undertaken as part of the routine road maintenance, with certain of these activities contributing insignificant proportions to the overall costs involved in routine road maintenance. For this reason the data was combined to indicate the primary cost activities as illustrated in Figure 3. This should not be construed as intimating that the minor cost items should be viewed as insignificant and not of importance, but merely illustrating the large cost items which are likely to impact a routine road maintenance budget most significantly, if either under- or over estimated.

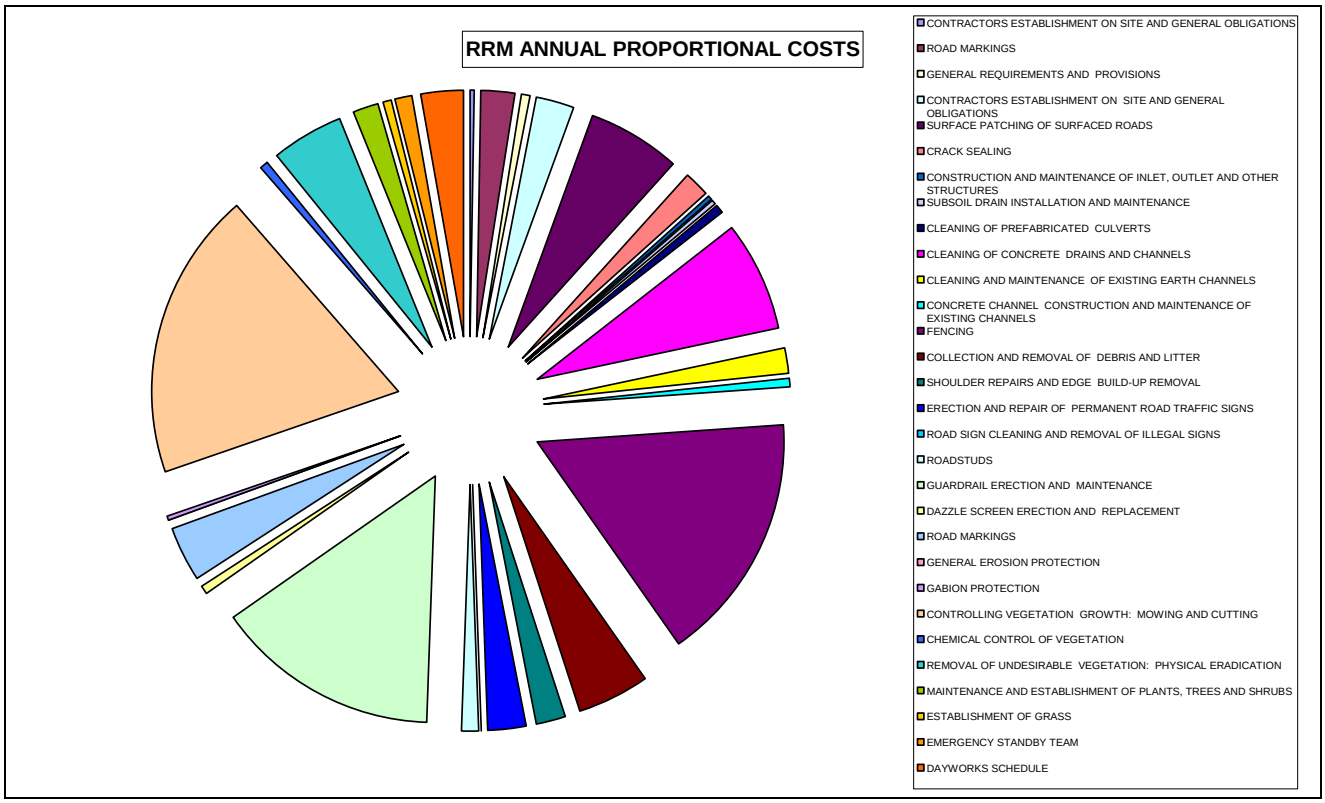

Figure 2: Breakdown of routine road maintenance activities by cost (dual carriageway)

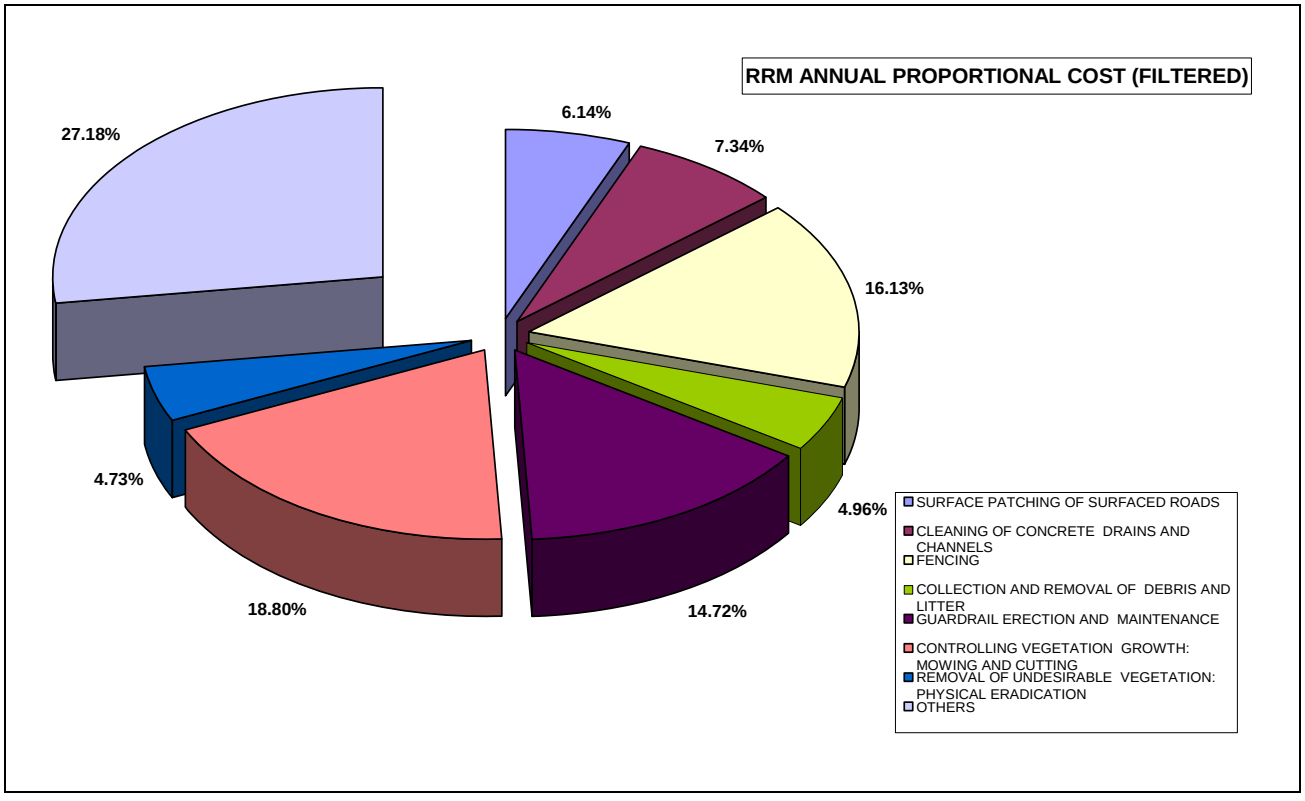

Figure 3: Breakdown of routine road maintenance activities by cost (Filtered)

Ironically the major contributions are made by activities such a vegetation control while the expected large cost items such a repairs to the road surface only contribute 7% of the total cost. Cognisance should however be taken of the high functional specification level applicable, the high traffic levels on this particular route, its strategic value to the country's economy and its continual management.

A number of routine maintenance initiatives related to the repair of the pavement prism are undertaken within the periodic maintenance and rehabilitation, reconstruction and upgrading strategy. For lower priority routes, periodic maintenance and structural strengthening will be required less frequently, and subsequently routine road maintenance will include significantly higher expenditure on items such as repairs to the road surface. Vegetation control is also heavily dependent on the climatic conditions and to a certain degree the road layout (dual versus single carriageway).

Routine road maintenance costs are reactive in nature for a large proportion of the activities undertaken. Thus potholes are repaired once they occur and road studs are generally replaced once they have been damaged. Figure 4 indicates the cost distribution of surface repairs over 2006 and confirms designers' conclusion that environmental conditions play a vital role in the deterioration of a pavement under traffic loading.

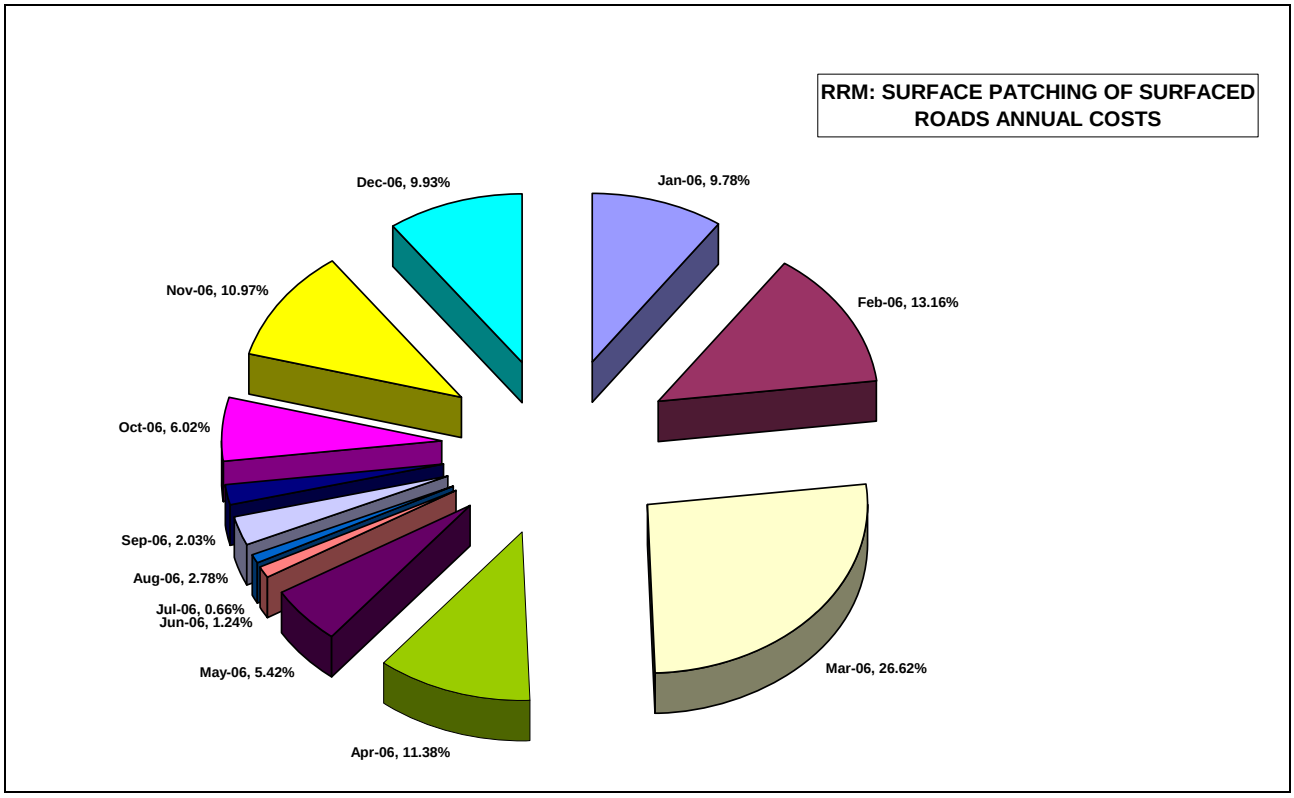

Figure 4: Distribution of surface repairs cost per month (year 2006)

4.2.2 Periodic maintenance costs

The periodic costs per km of pavement structure (flexible or rigid) for the N3 Toll Road are proportionally indicated in Figure 5. In Figure 5 periodic maintenance proportions include all proposed works that include only periodic maintenance activities. Due to the significant traffic loading along the N3 Toll Road a number of the periodic maintenance actions have been synchronised with the structural reconstruction and rehabilitation actions.

Subsequently the cost illustrated for flexible pavements' periodic maintenance was found to be lower than expected as a result of the combination of periodic maintenance activities

with rehabilitation, reconstruction and upgrade activities. The periodic maintenance proportional cost for rigid pavements provides a better differentiation between the structural rehabilitation, reconstruction and upgrades costs and the periodic maintenance costs due to the inherent structural capacity of the rigid pavements requiring minimal capacity upgrading over their design life.

4.2.3 Structural rehabilitation, reconstruction and upgrades

The structural rehabilitation, reconstruction and upgrades proportional cost per km of pavement is indicated in Figure 5. Using the same approach as discussed in Section 4.2.2, the structural rehabilitation, reconstruction and upgrades proportion is an overestimation for flexible pavements, including a number of activities that are designated as periodic maintenance.

4.2.4 Capacity improvements

Capacity improvement proportional expenditure per km is indicated in Figure 5. Capacity improvements represent a minor proportion of the maintenance cost. However, cognisance should be taken of the proposed construction of De BeersPpass to alleviate capacity concerns of van Reenen's with the next decade. This construction cost of De Beers Pass is not included within this analysis of maintenance costs represented in Figure 5, but is included in the total cost of maintenance.

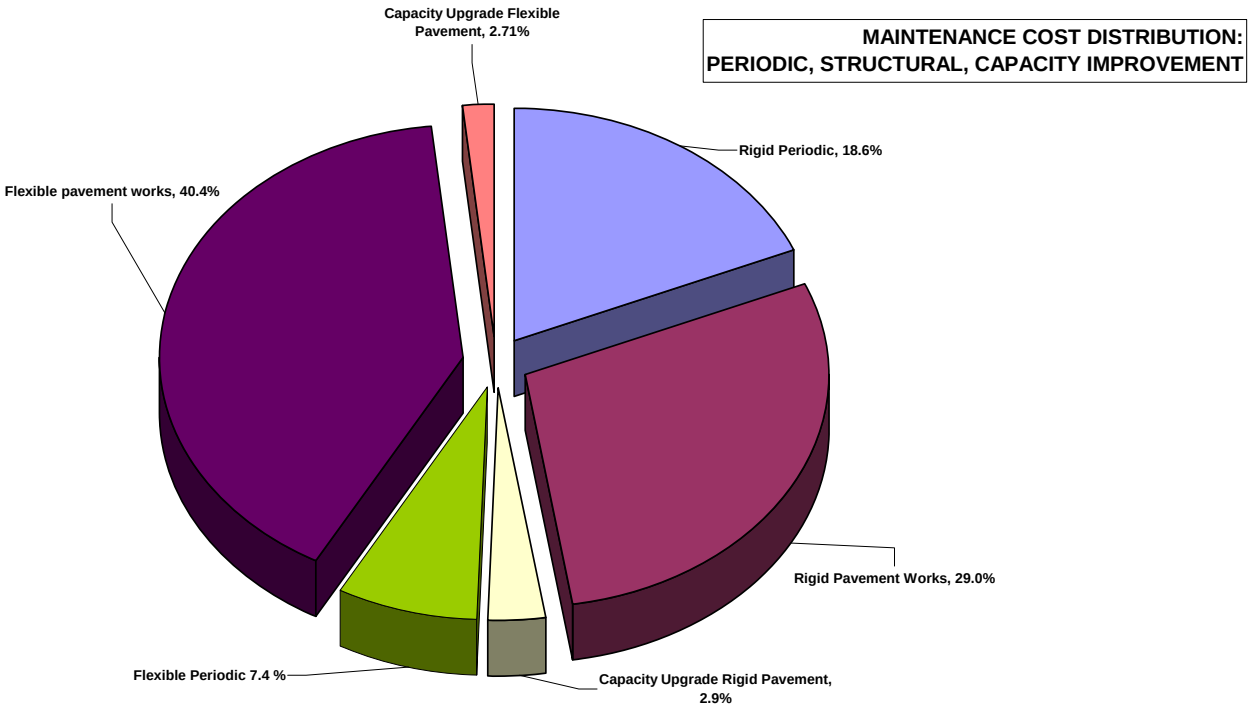

Figure 5: Comparison of periodic, structural and capacity upgrades cost distributions

4.2.5 Combined analysis

Figure 5 represents the proportional costs per km of maintenance on flexible and rigid pavements. The costs of maintenance of flexible pavements and rigid pavement are comparable on the N3 Toll Road on a per kilometer basis for each pavement structure. This is in direct contradiction to the generally accepted hypothesis that the increased cost of rigid pavement initial construction is negated over the design life of the pavement through lower maintenance costs over the life of the pavement.

Figure 5 should however be viewed from a position of considering the limited maintenance that has been undertaken on the rigid pavement structure over the last 30 years of its life. A maintenance backlog has been shown to negatively affect the maintenance and upgrading cost of a pavement structure. Figure 5 is a prime example of the effect of limited pavement maintenance (periodic or otherwise) on the overall maintenance costs. Part of the maintenance needs on the rigid pavements could also be as a result of deficiencies of the original design or construction, which is generally part of the learning of a new technology.

4.3 Estimated Maintenance Cost of Gauteng to Durban Road Corridor

Taking into consideration the maintenance cost derived for the N3 Toll Road and extrapolating this value over the entire length of the road corridor the maintenance cost of the road corridor over the 25 year design life can be estimated. No differentiation is made between flexible and rigid pavements since maintenance costs discussed in Section 4.2 indicate that the life cycle costs of the current pavement infrastructure is independent of the existing pavement structures due to the current age of the rigid pavement structures along the corridor.

The maintenance cost of the Gauteng to Durban Road Corridor is summarised in Table 3 below. Note that these values are dependent on the estimated traffic prediction and will vary depending on the total traffic and the traffic growth on an annual basis. The maintenance costs related to toll plazas and similar infrastructure required for toll road operations are not included within Table 3. These costs are viewed as operational costs and will be included within the analysis of operational costs of the Gauteng to Durban Road Corridor.

Table 3. Summary of Durban to Gauteng Road Corridor maintenance cost (25 year design life)

Cost Components	Value R mil (2006 Base year)
Periodic - Rigid	R 963.7
Structural and capacity - Rigid	R 1 656.1
RRM - Rigid	R 31.1
Periodic - Flexible	R 709.9
Structural and capacity- Flexible	R 5 608.7
RRM - Flexible	R 57.9
Total (516 km)	R 9 027.4

5. COMPARISON OF ROAD INFRASTRUCTURE COST

Significant uncertainty exists as to the actual maintenance 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;
- Varying level of service and categorisation discrepancies; and
- Funding availability.

This method of maintenance estimation is biased due to its reliance on budgetary allocations and not optimal maintenance requirements to minimise total life cycle cost. Estimates computed on budgetary expenditure are thus by their nature under-estimations in the context of road maintenance in South Africa.

Numerous local studies predict pavement maintenance costs based on actual expenditure. Table 4 provides a comparison between the lane-km maintenance cost of the Gauteng to Durban Road Corridor and various road projects maintenance 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 the maintenance of all structures along the route as well as the value of land and also includes the required capacity upgrades over the design life. Comparing the data in Table 4 it is evident that the Gauteng to Durban Road Corridor maintenance cost compares favourably with the national and international average values. The World Bank recommends that 1.5% of asset value should be spent annually on maintenance. Taking the infrastructure cost of the Gauteng to Durban of R7.225 million per lane km this equates to a maintenance expenditure of R108 000.00

Table 4. Comparison of annual maintenance cost

Country/ Province	Road Type/ Configuration	Value R /lane-km (2006 Base year)	Reference
South Africa (Average)	National roads	R 100 000.00	(NRA, 2003)
United Kingdom	4-lane highway	R 118 000.00	(Dept of Transport, 2000)
GAUTENG TO DURBAN CORRIDOR	4-lane dual and single carriageway	R 130 000.00	
Ireland	4-lane dual carriageway	R83 000.00	(Argus, 2004)

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

The maintenance cost of the Gauteng to Durban Road Corridor can be analysed in terms of the freight hauled along corridor. In order to perform such as 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.

The maintenance cost equates to a value of R 0.084/E80.km or R157/one directional trip for a freight haulier with a Gross Vehicle Mass equivalent to the average E80/HV of 3.5 (28 tonnes). This figure only takes into consideration the capacity upgrading, reconstruction, rehabilitation and routine road maintenance cost and excludes the operational costs required to maintain the Gauteng to Durban Road Corridor. It furthermore excludes the external costs related to environment and congestion. The maintenance cost is based on a defined design period of the road, in this case a period of approximately 25 years (23 years Concession and approximately 2 years remaining life). Note that external costs such as loan financing have not been included, and this means that operational costs cannot be simply calculated as replacement value plus maintenance cost.

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 maintenance cost presented in this paper is defined as the cost relating to the maintenance of the travelled way (the asset), to a set standard, as defined for a high-level national road.

Road maintenance cost can generally be classified into three distinct categories of routine road maintenance, periodic maintenance and structural reconstruction and upgrades.

The maintenance cost quantification is calculated upon actual priced road maintenance activities and interventions that have been extrapolated over the length of the Gauteng to Durban Road Corridor, taking into consideration the pavement structure differentiation between flexible and rigid pavements.

The maintenance cost presented in this paper is based on the provision of maintenance over the entire road corridor based upon the maintenance strategy adopted taking into consideration the current traffic predictions and existing pavement structural capacity. The current road maintenance cost of the Gauteng to Durban Road Corridor is quantified at

R 9.099 billion in 2006 monetary value over the 25 year design period, which is approximately 57% of the replacement value.

The maintenance cost per E80.km is on the Gauteng to Durban Road Corridor is

R 0.084/E80.km or R157/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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