FOUNDATION FOR A NATIONAL ROAD PRIORITISATION MODEL FOR SOUTH AFRICA

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DECLARATION

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LIST OF ABBREVIATIONS

Abbreviation	Meaning
2SFCA	Two-step floating catchment area
AADT	Annual Average Daily Traffic
ACI	Average Condition Index
ARDP	Access Road Development Plan
BCA	Benefit-cost analysis
CEA	Cost-effectiveness analysis
CIDB	Construction Industry Development Board
COTO	Committee of Transport Officials
DRPW	Department of Roads and Public Works
DPWRT	Department of Public Works, Roads and Transport
EOD	Environmentally Optimised Design
EPWP	Expanded Public Works Programme
FTE	Full-time equivalent
GAP	Geospatial Analysis Platform
GVA	Gross Value Added
HMD-4	Highway Development and Management Tool 4
IDC	Industrial Development Corporation
IDP	Integrated Development Plan
ILO	International Labour Organisation
IRI	International Roughness Index
LCCA	Lifecycle cost analysis
MTEF	Medium-term Expenditure Framework
NDOT	National Department of Transport
NDP	National Development Plan
NPC	National Planning Commission
NPV	Net Present Value
PRMG	Provincial Road Maintenance Grant

RAMP	Road Asset Management Plan
RAMS	Road Asset Management System
RIFSA	Road Infrastructure Strategic Framework for South Africa
RRAMS	Rural road asset management systems
RTMC	Road Traffic Management Corporation
RUC	Road user costs
SABITA	Southern African Bitumen Association
SADC	Southern African Development Community
SAICE	South African Institute of Civil Engineers
SANRAL	South African National Roads Agency
SAPDM	South African Pavement Design Method
TFP	Total factor productivity
TMH	Technical Methods for Highways
TRH	Technical Recommendations for Highways
VCI	Visual Condition Index
VGI	Visual Gravel Index
VOC	Vehicle operating costs
VPD	Vehicles per day

ABSTRACT

Inefficient road infrastructure investment in South Africa has led to five core policy failures: deterioration in road network conditions; neglect of citizens' constitutional rights of access to basic services; insufficient prioritisation of roads that best promote the general economy; an excessive rural road network; and application of inefficient road surfaces that increase road maintenance and road-user costs and fail to take advantage of the low shadow price of unskilled labour. The thesis first reviews the extent and consequences of these failures and evaluates their opportunity cost with respect to the potential benefits from more efficient road infrastructure investment policy. If fiscal constraints are accepted as exogenous given South Africa's politically driven budgeting process and the magnitude of road maintenance backlogs, then the question can be posed as to the capacity of the current maintenance scheduling systems to efficiently prioritise road investment according to the sector mandate to (i) satisfy citizens' right of access to constitutionally protected basic services, and (ii) maximally contribute to economic growth. The answer to this question is negative: the fact that none of the systems are appropriate to prioritisation explains the identified core failures. The thesis addresses this gap in several stages of analysis. The first stage is to develop a cost-effectiveness analysis-based road classification system that accounts for basic access and economic growth. This generates two important findings: most of the demand for access to basic services, which as per a normative economic framework based on arguments due to Rawls and Binmore is the first lexicographical policy priority, can be satisfied by roads that also support economic growth; and authorities can maintain Basic Access Roads and still have significant fiscal space within current allocations to maintain roads that optimally contribute to economic growth. The optimisation exercise proceeds through three stages. First, lifecycle cost analysis is applied to determine cost-effective surface solutions for low-volume roads, many of which are Basic Access Roads, and the employment benefits of a policy to seal low-volume roads. Second, a two-step floating catchment area model is used to identify potentially unproductive roads that may be cost-effectively rationalised through basic service hub relocation. With basic access rights satisfied efficiently, cost-effectiveness analysis is lastly applied to exploit the remaining exogenously given road budget allocation to develop and test a model of road maintenance prioritisation that optimises the sector's contribution to national economic growth via export promotion, which is identified in official literature as the primary variable under policy control to promote national economic growth.

EXECUTIVE SUMMARY

South Africa's road network is managed by a complex structure of national, provincial, and municipal road authorities. This structure requires an efficient road infrastructure investment policy to consistently ensure optimal expenditure outcomes across the sector. However, the requisite policy is absent and this has largely contributed to: deterioration in the road network conditions; neglect of citizens' constitutional rights of access to basic services; insufficient prioritisation of roads that best promote the general economy; an excessive rural road network; and application of inefficient road surfaces that increase road maintenance and road-user costs and fail to take advantage of the low shadow price of unskilled labour. This thesis develops the necessary policy framework to fundamentally resolve these failures.

The first step is to motivate the necessity of this goal through reference to the importance of road infrastructure in South Africa. This understanding is gained through the relevant road transport statistics and a theoretical production function supported by local information and case studies. Once the economic importance of road infrastructure is established, this thesis develops the following elements of an optimal road infrastructure investment policy:

A review of the factors affecting road authorities' investment operations. Identified in the performance records of the provincial and municipal road authorities are significant human resource constraints and road maintenance backlogs. The implication of this finding is that the incapacitated sub-national road authorities are forced into urgent need for investment prioritisation, which is set to persist over at least the medium to long term.

An assessment of the road investment prioritisation systems against the official mandate assigned to South African road authorities. None of the available prioritisation methods compare well against the two criteria that comprise the official mandate of South African road authorities: a constitutional obligation to address all citizens' rights of access to basic services, and to achieve efficiencies that best promote macroeconomic growth. Authorities thus require another method to systematically prioritise road infrastructure investment.

A cost-effectiveness analysis-based road classification system. This system is designed to account for the mandate of road authorities and is sensitive to the circumstances in South

Africa. The new road classes that are proposed can be integrated into road asset management systems in such a way as to: preserve basic access routes; prioritise investment in roads that maximise economic growth; and unproclaim roads that fulfil no basic access function whilst making negative contribution to economic growth in light of the opportunity cost of maintaining them.

Minimise the resource requirements to satisfy basic access rights. Optimal basic service hub locations are presented as an alternative to the continued maintenance of some specific basic access roads. Using GIS data, cases are identified in which, based on the trade-offs between road maintenance and the capital and current costs to create or relocate a basic service centre, authorities could potentially realise significant net saving from such action, which could then be directed to roads that maximise economic growth.

Minimise the lifecycle cost of roads. An optimal road surfacing policy is developed to cost-effectively inform authorities' design decisions. The policy recommendations are sensitive to a range of factors, including labour-intensive road works, the varying shadow price of labour across South Africa's provinces, and environmental features. The findings support the proposition that, in South Africa under its current economic and institutional conditions, roads worth maintaining at all should be sealed rather than maintained with gravel.

Maximise the contribution of the road network to macroeconomic growth. This requires an analysis of the channels by which road infrastructure contributes to macroeconomic growth in South Africa, and what type of roads make the greatest contribution to this growth. Cost-effectiveness analysis is applied to estimate and rank the relative contribution of a road to economic growth in terms of the objectives stipulated by the National Development Plan. As a case study, this method is applied to the provincial road network in Mpumalanga Province to generate a Prioritisation Index. This Index is assessed in relation to the historical budget allocations to demonstrate the practical value of the approach.

1 INTRODUCTION

1.1 PROBLEM STATEMENT

The South African roads sector is subject to a large fiscal constraint due to politically driven budgeting processes and high road maintenance backlogs relative to historical and forecast roads budget allocations. This constraint forces road authorities, including the 9 provincial and 234 municipal road departments, to undertake extensive road investment prioritisation exercises across the 750 000 km South African road network. However, this thesis identifies that the current road investment policy and set of road maintenance scheduling systems are unable to efficiently prioritise road investment according to the roads sector mandate to (i) satisfy citizens' right of access to constitutionally protected basic services, and (ii) maximally contribute to economic growth.

The inadequacies of the road investment policy and maintenance scheduling systems have contributed to five core policy failures: a significant deterioration in road network conditions; neglect of citizens' constitutional right of access to basic services; insufficient prioritisation of roads that best promote general welfare; an excessive rural road network; and application of inefficient road surfaces that increase road maintenance and road-user costs and fail to take advantage of the country's very low shadow price of unskilled labour. The opportunity cost of these policy failures with respect to the potential benefits from more efficient road infrastructure investment policy is high given that many rural communities fall outside the prescribed access norms and standards to basic service hubs, road infrastructure is South Africa's largest public asset, and most freight within South Africa is transported by road.

Despite the evident opportunity cost of these policy failures and calls for more efficient road investment by the National Development Plan (NDP), none of the current road investment models are appropriate to prioritisation. Road authorities must address the political economy issues of basic access rights and spatial inequality before it is possible to sustainably apply a national road investment prioritisation model focused on maximising economic growth. The first research objective is therefore to lay the foundation for a national road investment prioritisation model by addressing political economy factors and optimising the road network.

1.2 PURPOSE STATEMENT

The initial objective is to investigate the extent and consequences of the previously identified policy failures in the South African roads sector, and evaluate their opportunity cost against the potential benefits from more efficient road infrastructure investment policy. The present analysis provides a more detailed motivation for the research than that given by the National Planning Commission (2012) and National Department of Transport and demonstrates that the policy failures are ongoing issues. These policy failures are linked to the road investment and maintenance practices applied by the provincial and municipal road departments via an institutional review of the South African roads sector. According to Banister and Berechman (2003) this is a typical problem identification for countries with a developed road network.

This thesis then progresses through several stages of analysis to establish the foundation for a national road investment prioritisation model for South Africa. Stage one is to develop and test a cost-effectiveness analysis-based road classification system that accounts for the two functions stipulated by the road sector mandate: provide access to basic services and contribute to economic growth. Roads can then be consistently classified and prioritised according to the service, or combination of services, they provide. This classification system is a critical foundational element for a national road investment prioritisation model as it separates economic growth from the other political economy demands. Identifying the roads that satisfy citizens' right of access to basic services allows road authorities to prioritise this demand and confirms there is no risk of a Hobson's choice between neglecting basic access rights and neglecting the economic growth on which poverty rate reduction depends. This basis enables road authorities to confidently proceed with the application of a national road investment prioritisation model focused on maximising economic growth.

As part of the foundation for a national road investment prioritisation model this thesis also performs important optimisation exercises. The first two optimisation exercises investigate methods to efficiently satisfy basic access rights, thereby maximising the available budget for maintenance of roads that contribute to economic growth. The third optimisation exercise develops and tests a model of road maintenance prioritisation that optimises the sector's contribution to national economic growth via export promotion, which is identified in official literature as the primary variable under policy control to promote national economic growth.

1.3 FUNDAMENTAL CONSIDERATIONS

1.3.1 <u>Methodological approach</u>

Among the possible studies related to the problem statement in Section 1.1 are three high-level economic exercises. This thesis adopts a practical approach and develops a policy framework to efficiently allocate the available resources among the competing road projects. One alternative would be a conventional welfarist exercise to determine an optimal budget allocation for the roads sector as a function of a welfare optimising overall public expenditure schedule. Another alternative would be to evaluate the efficiency of the bargaining process that determines resource allocations to the roads sector using a public choice model.

Motivations favouring the practical approach over the welfarist exercise are given by Graaff (1963) and Sugden (2018). Graaff, who is one of the most important contributors to welfare theory and among the most influential South African economists, provides a detailed critique of the practical relevance of theoretical welfare economics. Given Graaff's scepticism about the practical value of standard neoclassical welfare theory, it is ironic that he engineered the system-wide reform of the post-apartheid South African Revenue Service and tax code - which proved remarkably successful. Importantly, Graaff only expresses scepticism about the practical usefulness of welfare theory after providing the most elegant consolidation of formal classical welfare theory conducted at the time (or, arguably, ever), as acknowledged by no less than Samuelson.

Graaff's (1963) scepticism about the practical usefulness of welfare theory focuses on three problematic conditions that must be satisfied in applications. Firstly, the choice of a time horizon is critical as it defines the group whose welfare is to be maximised. But as Graaff explains, a definite value judgement is required to determine the time horizon. Without a rational basis to choose a specific group demarcation or intergenerational discount rate, there is an arbitrary element at the foundation of any application of welfare theory.

Secondly, Graaff argues that any satisfactory theory of welfare must account for the external effects in consumption. However, economists generally ignore the extent to which individual tastes are moulded by social forces when deriving welfare function frontiers. Graaff's (1963) explanation for this oversight is that it is so hopelessly complicated to identify and estimate the external effects in consumption that large-scale policy applications will inevitably be hostage to heroic assumptions.

Thirdly, Graaff contends that there is no agreed basis for aggregating exogenous individual risk preferences to construct a social risk preference. Matters that require collective action therefore need a definite value judgement as to what constitutes the socially preferred level of risk. Without this the economist is unable to estimate the welfare effect of a policy.

Given these bases for scepticism, Graaff (1963) concludes that: "the greatest contribution economics is likely to make to human welfare, broadly conceived, is through positive studies – through contributing to our understanding of how the economic system actually works in practice – rather than through normative welfare theory itself."

Sugden (2018) criticises the practical relevance of conventional welfare economics due to its peculiar viewpoint. He contends that conventional welfare economics assumes a synoptic viewpoint, with the analyst taking a god-like position that is removed from the society whose well-being is assessed. This means that policy recommendations are typically addressed to an imagined benevolent dictator whose objective is to maximise the well-being of society. Sugden argues that there is little practical point to addressing policy advice to a non-existent, benevolent social planner focused on maximising the well-being of society. Real planners have neither the disinterested and universalist utility functions of the imaginary planner, nor the power to implement the kinds of general equilibrium solutions at which standard welfare analysis aims. Sugden concludes that economists should focus their advice on institutionally feasible recommendations addressed to actual agents who are able to act on the proposals.

Given that the South African roads sector budget allocation is exogenously determined via a political budgeting process, it promises little practical relevance to propose to policymakers an optimal roads maintenance allocation as a function of a welfare optimising overall public expenditure schedule. The road investment prioritisation model is developed conditional on the understanding that the roads sector budget parameters are exogenously fixed through political processes, then policymakers exercise discretion over how the available funds are allocated among the competing road projects. This context motivates my focus on ensuring available resources are efficiently allocated among the alternative road projects.

1.3.1.1 *Complementary research*

Recognising that roads sector budget allocations are exogenously set by political budgeting processes could motivate applying a public choice model to analyse the efficiency of this bargaining process. Public choice theory acknowledges that public officials are motivated partly by self-interest. Dunleavy (1991) explains that motivations in public officials' behaviour include a desire to select policies that advance their interests, specifically to maximise their budgets. Growth in a departmental budget helps to insulate senior officials from change, retain and improve human capital, facilitate economies of scale, and increase the prestige, income, and power of its managers (Dunleavy, 1991). The distortionary effect that public officials exert on resource allocations to and within the South African roads sector is currently unknown, and by implication how this bargaining process affects social welfare.

Interest groups also potentially influence public resource allocations in a liberal democracy such as South Africa. Interest groups lobby to demonstrate their preference intensities and thereby reweight policy in their favour. Lobbying activities are a form of rent seeking as they serve to transfer utility from one group to another, and the resources required to affect the transfer are potentially wasted. It is unknown what influence interest groups have on the South African roads sector budget allocation, but it may be significant as the sector draws attention from a wide range of interest groups that satisfy either one or a combination of the characteristics listed by Dunleavy (1991) for an effective lobby: large size, strong preference intensity, high rate of mobilisation, and a pivotal social or political position. Amongst the main roads sector interest groups in South Africa are the Southern African Bitumen Association[1] (SABITA), South African Roads Federation (SARF), Road Freight Association (RFA), South African Federation of Engineering Contractors, Consulting Engineers SA, and South African Institute of Civil Engineers. If these interest groups affect resource allocations to and within the roads sector, it is important to determine whether the lobbying activities improve social welfare and can thus be justified on normative grounds, or whether these activities tend to move outcomes away from the social welfare optimum.

The road investment prioritisation model developed in this thesis promotes export sectors, which are represented by influential lobbies. There are strong reasons to suggest that it is

[1] Disclaimer: SABITA provided financial and technical support for this thesis.

in the national interest to subsidise South African export sectors. For example, Section 1.3.3 identifies that South African export sectors are presently the most promising channels for generating the economic growth on which poverty rate reduction depends. However, a rigorous public choice model should be developed to test this hypothesis. The thesis leaves this exercise to future research.

1.3.2 South African spatial inequalities

Spatial inequality is among the key political economy factors that must be addressed for a national road investment prioritisation model focused on maximising economic growth to be sustainable. Economists have analysed the high and persistent spatial inequalities in South Africa in terms of economic activities and welfare outcomes (David et al., 2018; National Planning Commission, 2012; Fedderke and Wollnik, 2007). Seekings and Nattrass (2005) ascribe spatial disparities in South Africa to the legacy of racial separation under colonialism and apartheid, uneven natural resource endowments, and differences in public services, institutional capacity, and essential infrastructure. The apartheid development model sought to raise labour supply by resettling Africans from productive agrarian land to less productive native reserves, referred to as homelands, in which the apartheid state did little to promote separate development. In conjunction with strategic considerations, tax policies, and labour-market institutions that led to greater skill and capital-intensity in South African industries, Seekings and Nattrass (2005) conclude that this development model resulted in the growth of the wage labour force outstripping demand for labour while the subsistence and peasant farming sectors were weakened as alternative income sources. This development pattern undermined the degree to which spatial inequality might be reduced through factor mobility. The homelands, which comprised 13.0% of the land, subsequently degenerated into poverty whilst the apartheid state restricted urbanisation through influx controls such as the Group Areas Act of 1950. These factors explain why the poor are concentrated in rural areas.

The National Planning Commission (2012) note that spatial disparity in economic activities and welfare outcomes have in some respects worsened in the post-apartheid period. The World Bank (2018a) report that 65.4% of the 19.5 million people in rural areas lived below the poverty line of R992.0 per person per month in 2015, compared to 25.4% of the 35.9 million people in urban areas. 58.2% of poor citizens are therefore located in rural areas.

The World Bank (2018a) also find that poverty was more unequal and deeper, with more resources needed to lift the consumption expenditure of the poor up to the poverty line, in rural compared to urban areas. Estimates of poverty and inequality at the municipal level by David et al. (2018) confirm that most of the former rural homeland areas are among the poorest locations in South Africa.

Addressing this spatial inequality has featured prominently in South Africa's development policies since 1994. The NDP is guided by the need to respond to the entrenched spatial patterns that exacerbate social inequality and economic inefficiency (National Planning Commission, 2012). The NDP prioritises the need to address service backlogs in rural areas given the constitutional obligation to guarantee absolute minimum rights, specifically access to basic services, and commits to ensuring that rural areas are not written off as spaces with limited economic prospects (National Planning Commission, 2012). Addressing this issue of spatial inequality is therefore a vital component in setting the foundation for a national road investment prioritisation model for South Africa.

1.3.3 Export promotion

Although South Africa is classified as a middle-income country, the economy features a dual structure which Mbeki (2003) refers to as the first economy and second economy. The first economy reflects a relatively advanced capitalist economy and is modern, produces most of the country's Gross Domestic Product (GDP), and is integrated within the global economy. The second economy reflects a third world economy and is underdeveloped, contains a high proportion of the population including the urban and rural poor, contributes little to GDP, and is isolated from the first and global economies. The second economy is described by Mbeki (2003) as currently "incapable of self-generated growth and development" partly because of the low skills profile of the people in the second economy, the marginalisation of peasant farmers due to the previously explained concentration of fertile land in the first economy and existence of productive commercial farms, and constrained access for people in the second economy to resources.

Policy frameworks such as the NDP thus stress the importance of ensuring a strong first economy, which produces most output and hence income, to generate more resources to transfer into developing the second economy (National Planning Commission, 2012; Mbeki, 2003b). Official literature supports the policy position adopted in the NDP, 2011 New Growth Path, rolling Industrial Policy Action Plans, and the 2018 Integrated National Export Strategy to stimulate growth in the first economy via export promotion. Growth of the first economy is dependent on export growth for four main reasons: the first economy produces sophisticated goods intended for advanced economies, as demonstrated by the high proportion of exports to developed economies and the World Bank's (2014) finding that nonmineral and services exports from South Africa are more sophisticated than those of peer countries (IDC, 2017); the high-tech export sectors are the most efficient consumers of financial capital with the World Bank (2014) finding that the 'super-exporters', who in 2012 accounted for more than 90.0% of South African exports, focused their investments in technologically sophisticated, high value added products; domestic household consumption expenditure is constrained by the magnitude of the second economy, with 40.0% of the population living below the poverty line in 2015 (IDC, 2018; World Bank, 2018a); and government consumption expenditure is limited by the National Treasury's (2019) commitments to fiscal consolidation.

The road investment prioritisation model therefore prioritises road investments that promote export activity. This specific focus means the model will remain valid until such time as South Africa develops a sophisticated and robust internal demand base. But as this developmental outcome is at best a long-term prospect the model can be applied with confidence despite the relatively long life of road infrastructure. However, this focus on export promotion limits the direct applicability of the model to other developing countries characterised by a similarly sophisticated export sector, such as Brazil and Malaysia.

1.3.4 Focus on rural and peri-urban roads

While the cost-effectiveness analysis-based road classification system covers the full road network, the scope of the road investment prioritisation model is confined to South Africa's rural and peri-urban road networks, which comprised roughly 85.0% of the total road network in 2017. This delimitation is imposed when establishing the foundation for a national road investment prioritisation model for three reasons. Firstly, the road sector mandate to satisfy citizens' right of access to constitutionally protected basic services pertains to the rural and peri-urban road network as it is in these areas where basic service hubs tend to fall outside prescribed access norms and standards. Although this constitutional obligation is explicit, it has been viewed by public departments as a motherhood statement and selectively applied or merely rhetorically affirmed. The courts have contributed to the inconsistent application of this constitutional obligation by allowing government departments space to be practical (Dugard, 2016; Tissington, 2011). However, Binmore (1994; 1998) demonstrates that there is also a rigorous economic basis for giving operational weight to the constitutional clause for provision of basic services to the least well-off members of a population. Road authorities should first take fully seriously their constitutional obligation to provide all citizens with the required access to basic services before focusing on issues such as maximising economic growth or improving urban road networks.

Secondly, whereas road planners typically focus on dense urban road networks to promote economic growth, this approach is not entirely appropriate in South Africa given that a high proportion of the population, poverty, and export production, which was identified in Section 1.3.3 as vital to national economic growth, are located in rural and peri-urban areas. Export goods produced in rural and peri-urban areas, which includes the high volume of resources and agricultural goods exported from South Africa, must be transported across a relatively long network of rural and peri-urban roads before reaching urban roads and export points. This road network is therefore a logical starting point for analysis as these roads form both the initial and largest component of transportation costs for many export products.

Thirdly, rural and urban road networks are complex enough to warrant separate analyses. Both road networks cannot be adequately addressed by one thesis, especially given that congestion is the most important factor where the economics of urban roads is concerned. The foundation laid by this thesis for a national road investment prioritisation model sets a context in which urban road planners can focus on efficiently prioritising South Africa’s inner-city road networks, which predominantly fall within just 8 of South Africa’s 234 municipalities.

1.4 OVERVIEW OF THE THESIS

Chapter 2 provides the introductory information to understand the institutional arrangements for the South African roads sector and the contribution of road infrastructure to the country’s economy. Ownership of the 750 000 km South African road network is disaggregated among the national, provincial, and municipal spheres of government and unproclaimed roads. This information is primarily administrative and intended to inform readers who may be unfamiliar with the details and management of the South African road network. However, this network information is a useful reference for all readers as the network statistics are constantly being updated and it contextualise much of the subsequent economic analysis. This chapter also includes an accounting exercise to estimate the current and depreciated replacement value of the road networks. These estimates indicate that the road network is South Africa’s single largest public asset and that suboptimal road maintenance practices have eroded more than half of the value of this asset. The contribution of road infrastructure to the South African economy is further explored through analysis of statistical data on freight and passenger demand for road transport. Given the geographical characteristics and declining rail sector in South Africa, road transport currently accounts for approximately two-thirds of total land freight and is expected to remain the dominant transport mode for freight and passengers over the long term. Optimising road infrastructure investment is therefore amongst the most critical public infrastructure objectives in South Africa.

Chapter 3 evaluates the opportunity cost of investment policy failures in the South African roads sector with respect to the potential benefits from a more efficient investment policy. The evaluation combines a Cobb-Douglas model of output with case studies to demonstrate how road infrastructure investment influences economic growth via capital accumulation and total factor productivity gains. The discussion covers the preconditions for economic growth as public infrastructure investment is an insufficient condition for positive economic growth and can risk crowding-out private investment. Throughout the thesis it is important to bear in mind that economic returns from road infrastructure investments vary from relatively high to negative. The reality that road infrastructure investments can generate negative economic return is an important issue as the policy proposal made in the 2018 Draft Roads Policy for South Africa is to extend the road network by proclaiming unproclaimed roads, rather than unproclaiming unproductive roads. But if done efficiently, road infrastructure investment can help address the structural challenges that have led the South African economy into the low-growth middle-income trap and to achieve the economic growth targets set by the NDP.

Chapter 4 analyses the conditions under which road infrastructure investment policy is set and implemented in South Africa. The first condition that warrants attention is the road asset management maturity and skills profile of the road authorities. A practical motivation for a national road investment prioritisation model is the severe human resource constraints in many of the provincial and municipal road departments. The second condition investigated is the extent of the maintenance backlogs within the road networks, which are estimated for 2017 through an accounting-based exercise. The maintenance backlogs on the provincial and municipal road networks are found to be so large as to pose a significant fiscal constraint on these road authorities. This finding, in conjunction with the fact that the budget allocation for the roads sector is exogenously fixed through political processes, justifies the practical focus of this thesis on efficiently allocating the available resources amongst the alternative road projects.

Chapter 5 assesses the capacity of the current set of road maintenance scheduling systems to efficiently prioritise road infrastructure investment according to the official road sector mandate to (i) satisfy citizens' right of access to constitutionally protected basic services, and (ii) maximally contribute to economic growth. The conclusion, which is confirmed by a 2018 survey of senior provincial road department officials, is that none of the scheduling systems are appropriate to prioritisation. This analysis corroborates the calls by the South African National Treasury (2018a) and National Planning Commission (2012), which were assumed correct in the absence of adequate evidence, for a systematic road prioritisation system that accounts for the constitutional commitment to basic rights and resolves poorly coordinated intergovernmental planning, disconnects across municipal boundaries, and the inconsistent management of economic growth targets. This chapter is confined to a critique of current road maintenance scheduling systems in relation to the South African roads sector mandate, thereby reinforcing the need for the analysis that follows.

Chapter 6 is the first of four stages of analysis that systematically respond to the challenges identified in Chapters 4 and 5 and serves as the logical hinge point for the foundation for a national road prioritisation model for South Africa. This first stage is to develop and test a cost-effectiveness analysis-based road classification system that is sensitive to both the basic access and economic growth functions provided by a road. This system defines four road classes: Basic Access Roads; Strategic Roads; Tactical Roads; and Surplus Roads. The prioritisation rule applied to these road classes prioritises Basic Access Roads over the road classes that only support economic growth, namely Strategic and Tactical Roads, based on the constitutional mandate which is supported by arguments due to Rawls and Binmore. Two important preliminary conclusions are drawn from the analysis: most of the demand for access to basic services can be satisfied by roads that also support economic growth; and authorities can maintain Basic Access Roads and still have significant fiscal space within their current budget allocations to maintain roads that efficiently contribute to economic growth. These findings avoid a Hobson's choice between maintenance of roads that provide basic access and roads that maximise economic growth.

Chapter 7 performs the first of two optimisation exercises aimed at maximising the available budget for the maintenance of roads that maximise economic growth. Lifecycle cost analysis is applied to determine a cost-effective surfacing policy for low-volume roads, many of which are classified as Basic Access Roads. The analysis, which includes stress tests for the very low shadow price of unskilled labour and common factors that affect the frequency and cost of roadworks in South Africa, confirms that it is cost-effective to seal low-volume roads. The policy proposal to seal all low-volume roads worth maintaining at all at a rate possible within the exogenous fiscal constraints recommends an innovation in road surfacing convention in South Africa that would free up resources over the long-term for the maintenance of roads that promote economic growth. The analysis also links other potential welfare benefits with a policy to seal low-volume roads, including significant employment opportunities, skills and contractor development, substitution of local resources for imports, decreased rates of rural-urban migration, and all-weather road access to basic services.

Chapter 8 performs the second optimisation exercise to maximise the contribution of road maintenance policy to economic growth. This exercise applies a two-step floating catchment area model, which is a special case of gravity model, to identify potentially unproductive roads that may be cost-effectively rationalised through basic service hub relocation. Spatial accessibility to schools, healthcare facilities, and jobs are combined in a Multivariate Road Index, wherein the lowest priority class approximates the single-function Basic Access Road Network. Lifecycle cost analysis is used to estimate when it is efficient to trade off the cost to maintain single-function Basic Access Roads against the cost to relocate schools and healthcare facilities closer to relevant communities. Relocating basic service centres closer to isolated rural communities removes the access function served by these roads, meaning some can be unproclaimed without compromising citizens' basic access rights or economic growth. The potential net savings from rationalising the rural road network can be redirected to the maintenance of roads that maximise economic growth.

Chapter 9 develops and tests a model of road investment prioritisation for South Africa that exploits the remaining exogenously given roads budget allocation, following the efficient satisfaction of basic access rights, to optimise the sector's contribution to national economic growth. Analysis of the components of demand for goods and services produced in South Africa and reference to official literature confirm that export promotion is the primary variable under policy control to promote national economic growth in South Africa. The prioritisation objective is therefore to minimise the transportation costs imposed on the maximum volume of export freight for a given road maintenance allocation, thereby raising the productivity and international competitiveness of local export producers. Cost-effectiveness analysis is used to identify the sets of roads that minimise the transportation costs between suppliers and production and export points. While this approach cannot guarantee that a road project has a positive Net Present Value, it ensures that roads are properly evaluated relative to one another and given sufficient freight data that the prioritised roads support the highest volume of export freight for a given investment. The case study application of the road investment prioritisation model confirms that the model supports higher volumes of road maintenance and road freight under the same budget constraint, which likely generates an efficiency improvement although this cannot be confirmed due to the limitations associated with cost-effectiveness analysis.

2 THE ECONOMIC IMPORTANCE OF ROAD INFRASTRUCTURE

The South African economy is heavily reliant on road infrastructure. This dependence has predominantly been driven by three features: the country's geographic characteristics; the extent of the road network; and the decline in the competitiveness of the local rail sector. This chapter elaborates on these, and other key factors, to stress the current and long-term importance of road infrastructure to the South African economy.

Section 2.1 explores the size and ownership of the road network, which at 750 000 km is the 10^{th} longest globally (SANRAL, 2016). More impressive is the road network density, which at 614 754 km of road per million km^2 of surface area is the 5^{th} densest road network in the world. The extensive reach and high density of the road network means that most parts of the country are accessible via road, with multiple network connections and routes available in regions with higher levels of economic activity.

Section 2.2 uses public-sector accounting standards to estimate the value of the road network in terms of the current and depreciated replacement cost. The current replacement cost of the road network is estimated at R3.3 trillion in 2018, making it the country's single largest public asset. Even once the deterioration in road condition is considered the network is still valued at R1.4 trillion. The road transport asset base is therefore approximately twelve times larger than rail, its main competitor for freight and passenger transport, which by 2017 had fallen to only R229.0 billion (National Department of Transport, 2017a).

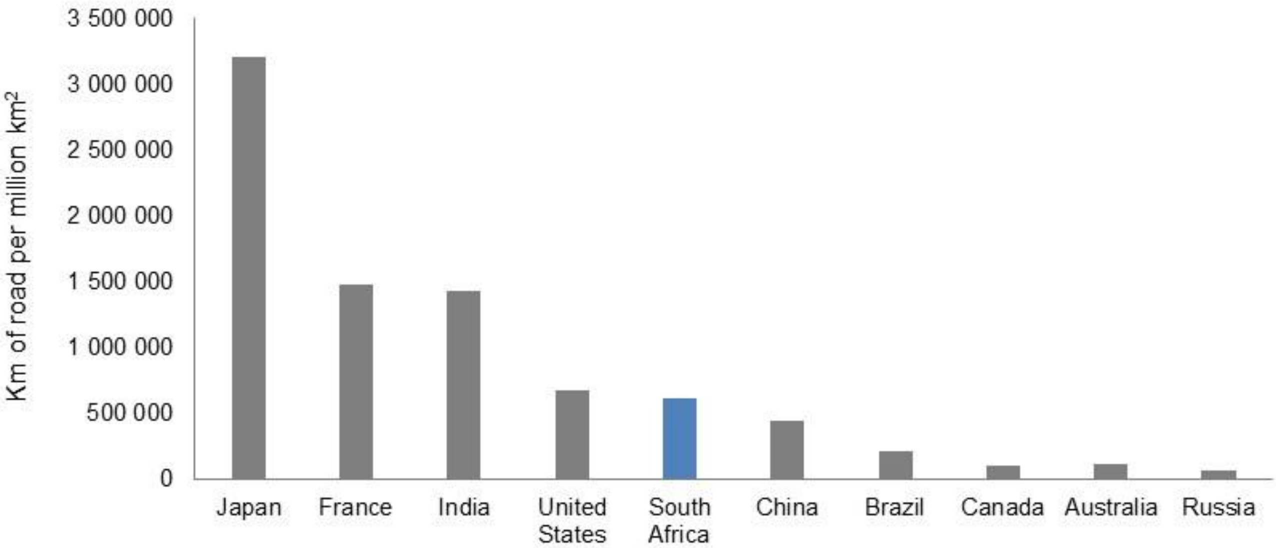
Section 2.3 analyses the contribution of road transport to GDP and growth in South Africa. This analysis is contextualised through reference to the country's geographic characteristics. 60.6% of South Africa's GDP in 2016 was generated by the inland provinces, with Gauteng province contributing 34.3% to this total. The approximate distance of 500 km between the industrial heartland in Gauteng province and the closest major port in Durban amplifies the transport intensity of many goods. When this transport intensity is coupled with the notable decline in the rail sector since the mid-1980s the result is that 61.1% of total land transport and 85.0% of general freight in 2014 was moved by road haulage. Despite the development of a National Rail Policy this heavy reliance on road infrastructure is forecast to persist over at least the medium to long term given the 30-year timeframe for the planned road-to-rail shift of rail friendly cargo, the long life-span of road infrastructure, the high level of private sector investment in roads-based logistics, and technological advances in road transport.

Section 2.4 lastly reviews the level of passenger demand for road transport. The volume of road users, assessed through the number of registered vehicles, has increased by 28.2% since 2010. This growth in vehicle population signals a strong level of household demand that is confirmed through reference to the high proportion of citizens who use road transport to access key points of interest.

2.1 THE SIZE AND OWNERSHIP OF THE ROAD NETWORK

The total South African road network is approximately 750 000 km. The 163 472 km of paved roads within this total network places South Africa 18th in terms of the volume of surfaced roads (SANRAL, 2016). Figure 2.1 analyses and compares the extent of the South African road network in relation to surface area. With 614 754 km of road per million km^2 of surface area, the density of the South African road network is comparable with developed countries and its BRICS partners. This relatively high level of service demonstrates that South Africa has a mature road network that resembles developed rather than developing countries.

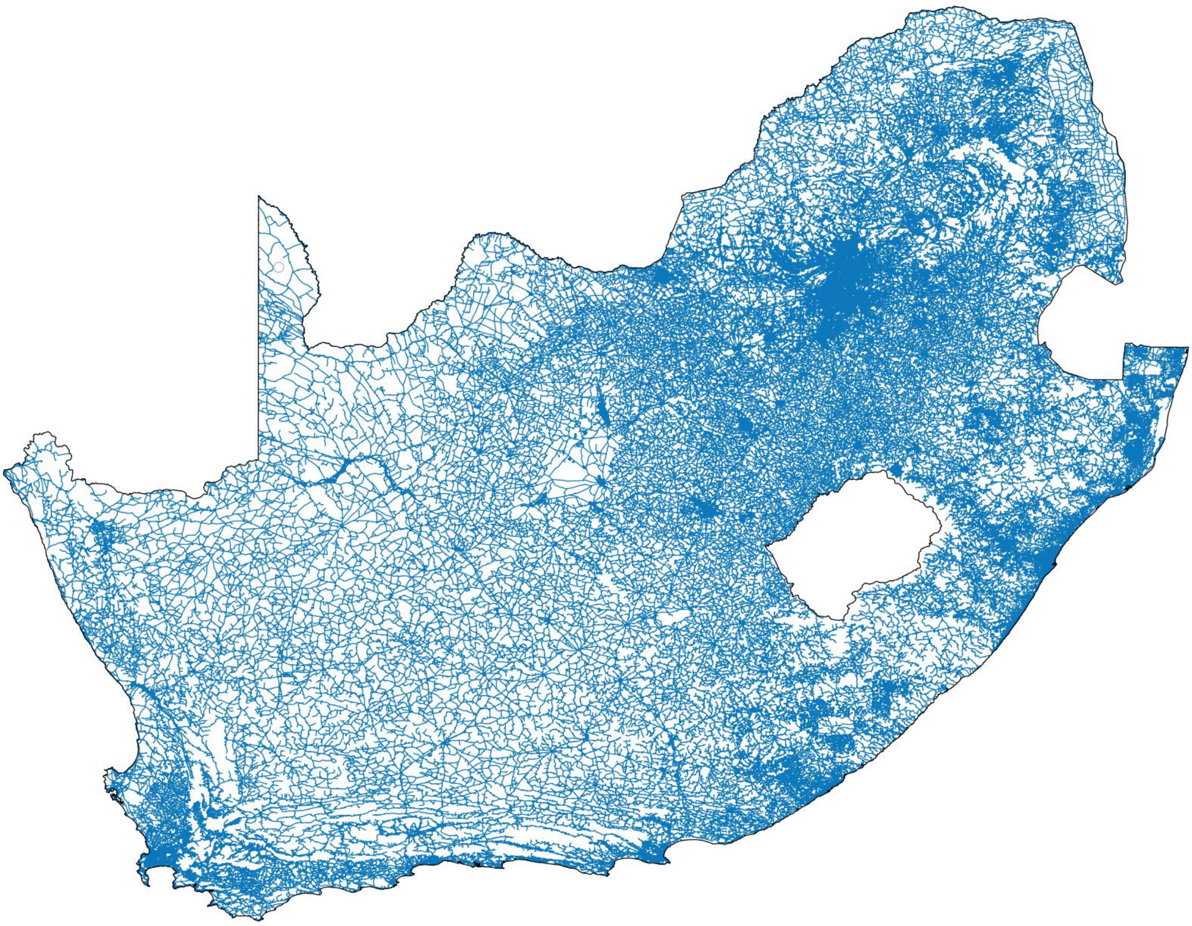
Figure 2.1: Road network density, 2016



Source: SANRAL, 2016; World Bank, 2018b.

Figure 2.2 maps the recorded South African road network. The Figure shows that the road network extends across the country, supporting activity in both urban and rural regions. The high number of connections suggests that there is a high degree of first and last mile access along with many cross-country mobility routes. The road density is visibly higher in certain areas, which tend to mirror the urban boundaries and regions with more economic activity.

Figure 2.2: The South African road network



Source: CSIR, 2011.

Ownership of this extensive road network is decentralised among the national, provincial, and municipal spheres of government. There are also unproclaimed roads that are yet to be formally classified as the responsibility of any sphere of government. Most unproclaimed roads are in the former homeland regions and fell out of the proclaimed road network during the transition from the apartheid era road network structures.

The South African Local Government Association (2012) criticised the repeated and notable discrepancies in the sub-national road ownership profiles. This trend has continued, with the provincial and municipal road networks revised in 2016 from 184 816 km and 405 992 km to 273 078 km and 323 057 km, respectively (National Treasury, 2011a; SANRAL, 2016). Yet in 2017 the provincial Road Asset Management Plans (RAMPs) captured the provincial road network at only 222 677 km. While some of the discrepancies in road ownership relate to transfers amongst authorities, extensions of the network, and proclamations, the National Department of Transport (NDOT) attribute most of the data discrepancies to poor provincial and municipal reporting that in turn has led to an out-of-date national public road inventory (Parliamentary Research Unit, 2012).

Table 2.1 presents the ownership statistics reported by the road departments and agencies. This ensures that the data are current and that the classified roads are known to and actively managed by the respective authorities. The ownership profiles are based on SANRAL's (2017) Integrated Report, the most recently available provincial RAMPs and annual reports, and the Rural Road Asset Management Systems (RRAMS) data reported by the district municipalities. Insufficient self-reporting by the cities required ownership data for the metropolitan roads to be sourced from SANRAL (2016), which was cross-checked against the statistics used by Committee of Transport Officials (COTO) (2014). The unproclaimed road network was also last reported in 2016 by SANRAL (2016). Revisions to the ownership of metropolitan and unproclaimed roads is therefore a possibility.

Table 2.1: Ownership of the South African road network, 2017

Authority	Sealed (km)	Gravel (km)	Total (km)	Network split
SANRAL	**22 197**	**0**	**22 197**	**3.0%**
Provinces	**48 945**	**173 732**	**222 677**	**29.7%**
Municipalities	**92 330**	**280 877**	**373 207**	**49.7%**
Metropolitans	51 682	14 461	66 143	8.8%
District municipalities	40 648	266 416	307 064	40.9%
Unproclaimed roads	**Unknown**	**Unknown**	**131 919**	**17.6%**
Total	**163 472**	**454 609**	**750 000**	**100%**

Source: SANRAL, 2017; Eastern Cape Department of Roads and Public Works, 2017; Free State Department of Police, Roads and Transport, 2017; Gauteng Department of Roads and Transport, 2017; KwaZulu-Natal Department of Transport, 2017; Mpumalanga Provincial Government, 2016; North West Department of Public Works and Roads, 2016; Northern Cape Department of Roads and Public Works, 2017; Roads Agency Limpopo, 2017; Western Cape Department of Transport and Public Works, 2017; National Treasury, 2018a; National Department of Transport, 2017b.

2.2 THE ACCOUNTING VALUE OF THE ROAD NETWORK

The most recent estimate of the accounting value of the road network was done for 2013 by COTO (2014). Although 5-years out of date, COTO's estimate of R2.1 trillion remains the most commonly referenced road asset value and was used in the 2018 Draft White Paper on Roads Policy for South Africa (National Department of Transport, 2018a). COTO (2014) also estimated that the depreciated replacement cost of the road network was R1.2 trillion, or 54.8% of the current replacement cost. It is important to emphasise that the current and depreciated road network replacement costs are strictly static and reflect accounting value rather than the economic value. The economic value assessment of the road network is addressed in Chapter 9.

COTO's (2014) study, however, was based on a very limited sample of road condition data and unverified and unadjusted sub-national road construction costs. The following estimates for the current and depreciated road network replacement costs draw on data compiled for this thesis and used in the National Treasury's (2018a) Road Network Cost Model. A 4-step process aligned with the TRH 22 recommendations was followed to compile the dataset: a first principles approach was adopted in consultation with three experienced pavement engineers to determine competitive task rates and unit costs for the categories of road works[2] on 14 road surfaces[3] with varying traffic volumes[4]; the task rates and unit costs were cross-checked against the information reported in the provincial RAMPs and the tender documents collected as part of the Provincial Roads Performance and Expenditure Review for the National Treasury's (2018a) Government Technical Advisory Centre (GTAC); another cross-check of the task rates and unit costs was performed by the Southern African Bitumen Association (SABITA) for a series of local and international conference presentations that applied the data; and the final verification was done by the National Treasury who sent the dataset to the provincial road departments for comment. The Road Network Cost Model was distributed by GTAC to the provincial road departments as a tool to help engage with the project specifications produced by consultants and to guide tender evaluations.

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[2] Construction; routine maintenance; periodic maintenance; minor rehabilitation; and major rehabilitation.

[3] Gravel; sand seal; slurry seal; 14mm cape seal with 1 slurry; 14mm + 7mm double seal; geotextile seal; split seal; choked seal; inverted seal; segmented block paving; 30mm hot mix asphalt (HMA); 40mm HMA; 50mm HMA; and ultra-thin reinforced concrete paving.

[4] Low volume (AADT ≤ 219); low-medium volume (220 ≤ AADT ≤ 499); medium volume (500 ≤ AADT ≤ 999); medium-high volume (1000 ≤ AADT ≤ 2999); and high volume (AADT ≥ 3000).

2.2.1 The current replacement cost of the road network

The Public Finance Management Act (1999) requires national and provincial government departments to prepare annual financial statements in accordance with the recognised accounting practice. The Treasury Regulations set the Modified Cash Standard (MCS) as the recognised accounting practice (National Treasury, 2017). The MCS requires immovable capital assets, such road infrastructure, to be recorded in the asset register at their cost. This cost reflects the amount paid to construct the asset, or where that cannot be determined the asset's fair value, and is not subject to readjustment for depreciation.

Municipalities and public entities, such as SANRAL, are governed by the Municipal Finance Management Act (2003) and must comply with the Standards of Generally Recognised Accounting Practice 17 (GRAP 17). GRAP 17 also requires that an immovable capital asset like roads be measured at its cost, or where that information is not available its fair value. But unlike MCS, GRAP 17 requires that infrastructure assets are carried at their cost less any accumulated depreciation.

Momentarily setting aside the matter of depreciation, the Technical Methods for Highways (TMH) 22 states that the current replacement cost for road assets must reflect the fair value for what it would cost to replace a road based on the current rates (COTO, 2013). The methodology is shown in Equation 2.1 and calculates the current replacement cost based on the product of the quantity of the component type and its corresponding current unit rate.

$$\text{Current replacement cost} = \text{Current unit rate} \times \text{Quantity of component} \qquad 2.1$$

Table 2.2 presents the road replacement unit rates used by COTO (2014), with annual roadwork inflation applied to convert the rates from 2013 to 2018 values (Statistics South Africa, 2018a). COTO's unit rates are compared with revised road construction costs from the National Treasury's (2018a) Road Network Cost Model, which were weighted according to the traffic volume information shown in Table 2.3 to account for differences in pavement structures and surface types across each authority's road network. The limitations of the traffic data include the aggregation of district municipality paved and gravel roads and the assumption that the metropolitan traffic profile mirrors provinces.

Table 2.2: Current road replacement costs per km, 2018

Authority	Sealed roads		Gravel roads	
	COTO cost	**Revised cost**	**COTO cost**	**Revised cost**
SANRAL	R19 329 600	R19 329 600	N/A	N/A
Provinces	R10 178 968	R8 737 822	R1 577 982	R3 073 600
Metropolitan	R5 902 840	R8 737 822	R1 577 982	R3 073 600
District Municipalities	R4 427 176	R4 072 476	R1 577 982	R3 011 860
Unproclaimed roads	N/A	N/A	R946 789	R3 000 000

Source: COTO, 2014; National Treasury, 2018a.

Table 2.3: Road traffic volumes, 2017

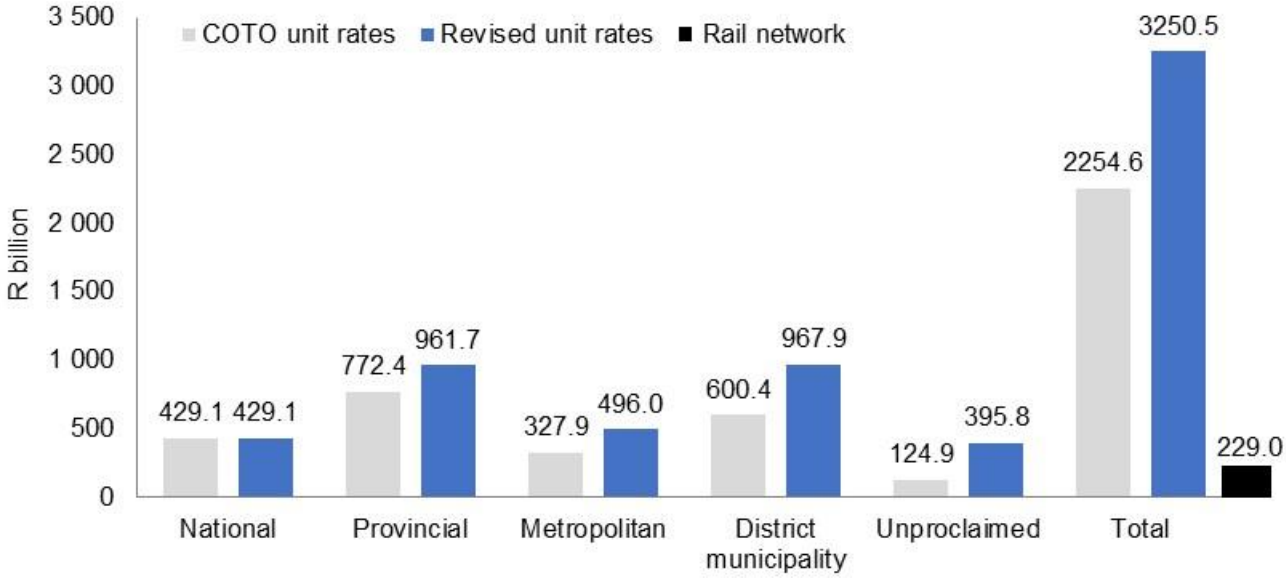
Authority	Low-volume		Medium-volume		High-volume	
	Gravel	Sealed	Gravel	Sealed	Gravel	Sealed
National	N/A	0.0%	N/A	0.0%	N/A	100.0%
Provincial	84.0%	30.0%	8.0%	26.0%	8.0%	44.0%
Metropolitan	84.0%	30.0%	8.0%	26.0%	8.0%	44.0%
District Municipality	95.4%	95.4%	3.8%	3.8%	0.8%	0.8%
Unproclaimed	100.0%	N/A	0.0%	N/A	0.0%	N/A

Source: Eastern Cape Department of Roads and Public Works, 2017; Free State Department of Police, Roads and Transport, 2017; Gauteng Department of Roads and Transport, 2017; KwaZulu-Natal Department of Transport, 2017; Mpumalanga Provincial Government, 2016; North West Department of Public Works and Roads, 2016; Northern Cape Department of Roads and Public Works, 2017; Western Cape Department of Transport and Public Works, 2017; National Department of Transport, 2017b.

The most notable differences between the unit rates used by COTO (2014) and the adjusted unit rates are the construction costs for metropolitan paved roads and gravel roads. COTO's unit rates to construct metropolitan paved roads equates to the construction cost for a double seal on a medium-volume road (500 ≤ AADT ≤ 999) or a 30mm hot mix asphalt surface on a low-medium volume road (220 ≤ AADT ≤ 499). Given the relatively high traffic volumes in metropolitan cities these two road surfaces would be underspecified for the required level of service and therefore underestimate the actual cost. Moreover, COTO's unit rates for gravel roads seemingly apply a lower design specification than prescribed for low-volume roads by manuals - such as the Western Cape Government's Geometric Manual (2006) - and assume that unproclaimed roads are not engineered. While some unproclaimed roads are dirt roads and tracks, many were properly constructed but then dropped from the formal network on administrative, financial, and capacity grounds rather than for design reasons. The unit cost for unproclaimed roads is likely between the COTO and revised cost, but this determination requires currently uncollected data on the composition of this network.

According to the unit rates in Table 2.2 and the quantity of components from the ownership data in Table 2.1, the total and disaggregated current replacement costs of the road network in 2018 are presented in Figure 2.3. COTO's (2014) unit rates set the current replacement cost at R2.3 trillion, whereas the revised unit rates push this value upwards to R3.3 trillion. Based on the revised unit rates the most valuable asset is the district municipality network at R967.9 billion, followed by the provincial road network at R961.7 billion, the metropolitan road network at R496.0 billion, and the national road network at R429.1 billion. Although unproclaimed roads are not accounted for by any road authority, the upper-bound value of this asset is estimated at R395.8 billion.

Figure 2.3: Current replacement cost of the road network, 2018



Source: Own estimates.

There is a clear mismatch between the road and railway asset bases. Each authority's road network is more valuable than the entire railway network which was valued at R229.0 billion in 2017 (National Department of Transport, 2017a). The total value of the road network is approximately 12 times the current replacement cost of the railway network. But the primary comparison is between the value of the railway network and the national road network as these directly compete for cross-country freight and passenger transport. This analysis puts the current replacement cost of the national road network at 1.89 times the railway network.

2.2.2 The depreciated replacement cost of the road network

The MCS and GRAP 17 allow for the determination of fair values for road assets using the depreciated replacement cost, which adjusts the current replacement cost for any wear or consumption to reflect the remaining service life of the road. Equation 2.2 calculates the depreciated replacement cost and is based on TMH 22 and the National Treasury's (2008) Local Government Capital Asset Management Guideline as neither MCS nor GRAP 17 detail how the depreciated replacement cost should be calculated.

$$\text{Depreciated replacement cost} = \text{Current replacement cost} \times \frac{Remaining\ useful\ life}{Estimated\ useful\ life} \qquad 2.2$$

Based on the assumption that asset life is directly proportional to asset condition, the cost of a road in less than perfect condition is less than the current replacement cost in proportion to the prevailing condition of the road. This makes the current condition of the road a proxy for the road's remaining useful life. As per Roux *et al.* (2018) Equation 2.2 can therefore be rewritten as Equation 2.3.

$$\text{Depreciated replacement cost} = \text{Current replacement cost} \times \text{Average Condition Index} \qquad 2.3$$

The Average Condition Index (ACI) is a measure of the present road condition, varying from 0.0% (completely deteriorated) to 100.0% (perfect condition). This study uses the weighted average Visual Condition Index (VCI) for all roads and is calculated in Equation 2.4 by multiplying the percentage of the road network in each condition category by the average VCI-value of that category (Automobile Association of South Africa, 2008). The requisite data to calculate the ACI for the South African road network is given in Table 2.4 and was sourced from SANRAL (2016), the provincial RAMPs, and the NDOT's (2017b) RRAMS database. The weighted ACI for the total proclaimed road network was 47.8 as at the end of 2017, but when the unproclaimed road network is factored in the ACI falls to 42.5. These are both notably lower than the weighted ACI of 54.8 applied by COTO (2014).

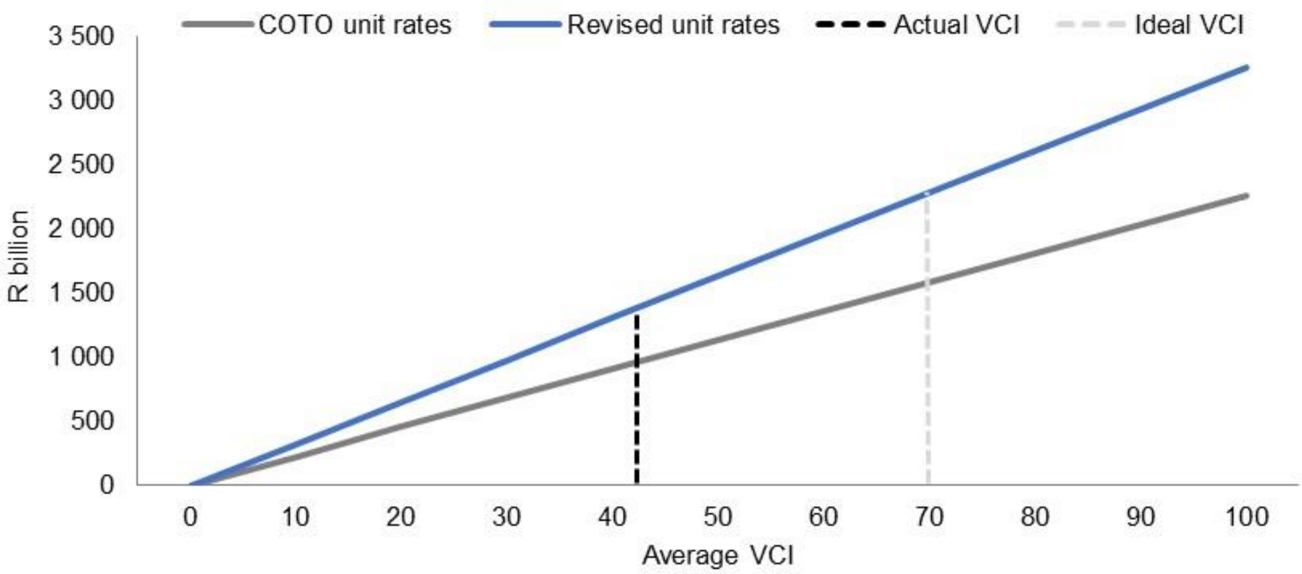
$$\begin{aligned} \text{ACI} = (&km_{very\ poor} \times 17.5 + km_{poor} \times 42.5 + km_{fair} \times 60.0 + km_{good} \times 77.5 \\ &+ km_{very\ good} \times 92.5)/100 \end{aligned} \qquad 2.4$$

Table 2.4: Visual Condition Index rating of the South African road network, 2017

Road group	Visual Condition Index				
	Very poor (VCI < 35)	Poor (35 ≤ VCI ≤ 50)	Fair (50 ≤ VCI ≤ 70)	Good (70 ≤ VCI ≤ 85)	Very good (85 ≤ VCI ≤ 100)
Sealed	9 918 km	21 392 km	47 414 km	53 826 km	30 922 km
Gravel	146 875 km	193 387 km	70 224 km	33 994 km	10 129 km
Proclaimed	156 793 km	214 780 km	117 638 km	87 820 km	41 051 km
Unproclaimed	131 900 km	0 km	0 km	0 km	0 km
Total	288 693 km	214 780 km	117 638 km	87 820 km	41 051 km

Figure 2.4 illustrates the 2017 depreciated road network replacement cost. The depreciated replacement cost of the road network is estimated at R958.2 million if COTO's unit rates are used and at R1.4 trillion according to the revised unit rates. Both estimates are significantly lower than their respective ideal depreciated replacement values, which were set at 70.0% of the current replacement value as this ACI corresponds with the international benchmark that 10.0% of roads can be in poor to very poor condition. Despite the deadweight loss from the excessive deterioration of the road network, both sets of depreciated replacement costs indicate that the network remains a significant asset even after depreciation is considered.

Figure 2.4: Depreciated replacement cost of the road network, 2017



Source: Own estimates.

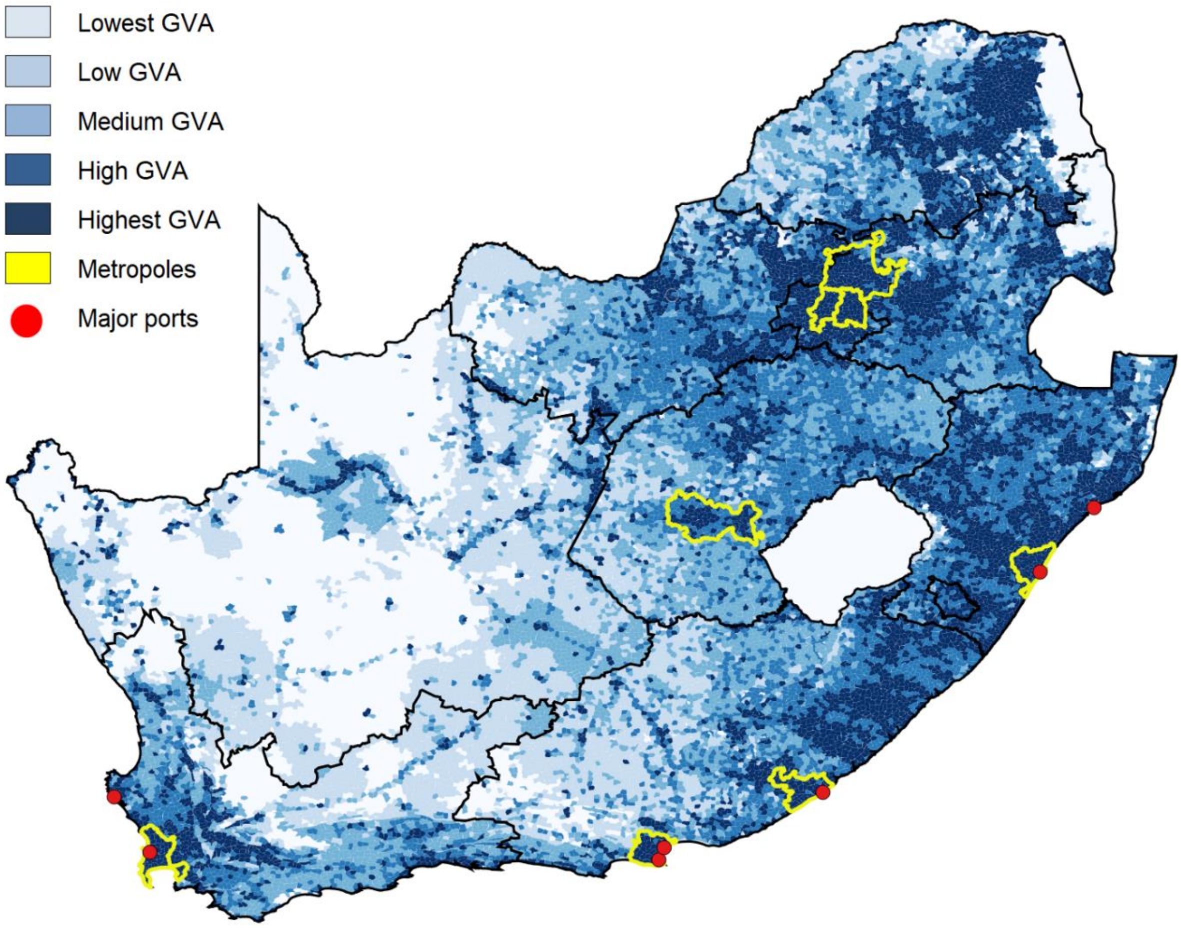
2.3 THE CONTRIBUTION OF ROAD TRANSPORT TO GDP AND GROWTH

Transportation is directly linked to a level of output, employment and income within a national economy. Data from the South African Reserve Bank (2018) indicates that the transport, storage, and communication sector, of which road transport is a notable component, directly contributed 8.6% to GDP in 2017. This value refers to the resources devoted to moving and storing goods and not to the value of the goods being moved or stored. This combined sector has experienced consistent growth over the last 50 years and contributed 0.8% and 1.5% to real GDP growth in 2016 and 2017, respectively.

South Africa's geographic characteristics raise the relative transport intensity of many goods and services. Figure 2.5 illustrates the distribution of Gross Value Added (GVA), major ports, and metropolitan municipalities. The metropoles accounted for 39.7% of the total population in 2016 and thus represent a major portion of local demand (Statistics South Africa, 2016). Figure 2.6 also shows high volumes of production are inland, with Gauteng, Mpumalanga, Limpopo, North West, and Free State provinces respectively contributing 34.6%, 7.4%, 7.2%, 6.4%, and 5.0% to GDP in 2016 (Statistics South Africa, 2016). The inland provinces are separated by significant distances from major ports (approximately 500 km for Gauteng) and, except for Gauteng and Free State, are also removed from the metropolitan markets.

Transport needs are additionally affected by trade and product profiles. South Africa has a diversified demand and production profile, with a total of 4 481 import products and 4 492 export products in 2016 (World Integrated Trade Solution, 2018). This high level of diversity implies more production and consumption points. The value of imports and exports equalled 28.4% and 29.8% of GDP in 2017, respectively, with both set to increase as a share of GDP over the Medium-term Expenditure Framework (South African Reserve Bank, 2018; National Treasury, 2018b). Over-and-above bulk products, imports totalled 1.1 million Twenty-foot Equivalent Units (TEUs) and exports 1.3 million TEUs in 2014 (Havenga *et al*., 2016). This combination of geographic and trade features necessitates extensive freight movement and corridors, with total land freight in South Africa recorded at 848 million tonnes or R832 billion in 2014 (Havenga *et al.*, 2016).

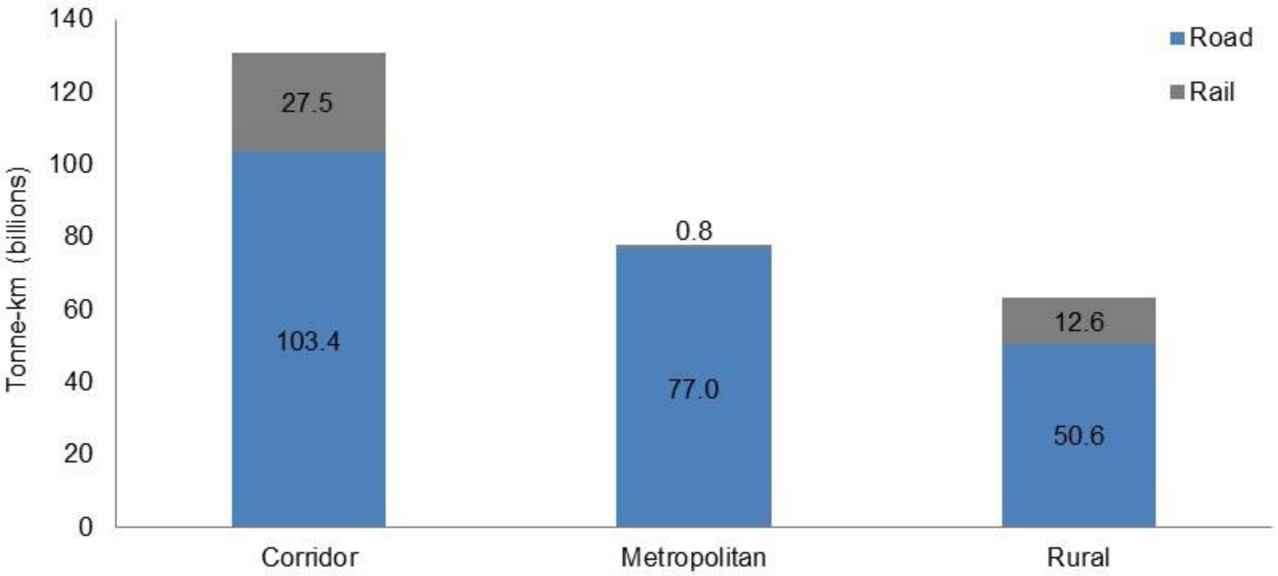
Figure 2.5: Geographic distribution of GVA, major ports, and metropolitan municipalities



Source: CSIR, 2010; CSIR, 2011; Statistics South Africa, 2011.

Road transport accounted for 231 billion tonne-km of land freight flows in South Africa in 2014 (Havenga *et al.*, 2016). This equates to 61.1% of the total land freight flow. If dedicated rail and pipeline transport systems are removed, then road transport was responsible for 85.0% of all general freight in 2014. Figure 2.6 shows the typological division of general freight transport, with roads the predominant transport means in both metropolitan and rural areas and along transport corridors. While this intermodal freight split is perceived as being skewed towards roads, this trend in road dominance is becoming increasingly common. For example, road transport accounted for 76.4% of total tonne-kilometres of inland freight in 2016 for the 28 Eurozone countries with this proportion as high as 99.1% in Ireland, 98.7% in Greece, 94.7% in Spain, and 91.5% in the United Kingdom (Eurostat, 2018).

Figure 2.6: Typological division of general freight transport in South Africa, 2014



Source: Havenga *et al.*, 2016.

Table 2.5 presents key trade details for the major national transport links carrying the largest freight volumes. The respective volumes of road and rail freight are compared, with roads often the dominant mode except for the corridors focused on primary resources. In line with the GVA distribution presented in Figure 2.5, the Gauteng-based links account for 65.5% of total road tonnes. The variety of commodities transported along the corridors demonstrates the cross-sectoral reliance on road infrastructure. The National Development Plan (NDP) therefore identified the strengthening and optimisation of these corridors as a key economic priority (National Planning Commission, 2012).

Table 2.5: Total road and rail freight on major transport corridors, 2013

		Million tonnes	
Network section	**Freight commodities**	**Road**	**Rail**
Gauteng-Durban	containers, steel, cars, coal, manganese, fuels, perishables	44.0	24.0
Gauteng-Swaziland	beverages, cement, coal, vehicles, grains, sugar	38.0	0.0
Cape Town-Port Elizabeth	cars, fuels, fruit, perishables, steel, tyres	37.0	0.3
Gauteng-Cape Town	cars, grains, containers, perishables, cement, steel	15.0	11.0
Gauteng-Musina	foods, fuels, vehicles, cement, perishables, beverages	12.0	4.5
Gauteng-Ressano Garcia	mineral ore, fruit, sugar, timber, cars, paper	8.0	7.0
Durban-Pongola	containers, fuel, chemicals, timber	7.0	5.2
East London-Durban	beverages, foods, fuels, vehicles	6.0	0.0
Gauteng-Tlokweng	fuels, cement, containers, vehicles, food	6.0	2.0

Winburg-Harrismith	maize, livestock, perishables, steel, containers	5.8	0.0
Cape Town-Namibia	fish, containers, fertilisers, cement, machinery	4.0	0.0
Thaba Nchu-Maseru	containers, fuel, cement, grains, coal, foods	3.0	0.0
Gauteng-Upington	foods, cement, steel, machinery, vehicles, perishables	2.1	0.7
George-Colesberg	fuels, grains, perishables	1.6	0.0
East London-Bloemfontein	vehicles, steel, grains	1.2	1.6
Britstown-Nakop	food, cement, steel, machinery, cars, perishables	0.2	0.7
Ermilo-Richards Bay	coal, steel, timber, chrome	0.0	78.0
Sishen-Saldanha	iron ore, lead	0.0	62.0
Total		**190.9**	**197.0**

Source: Draft National Freight Logistics Strategy Review, 2015.

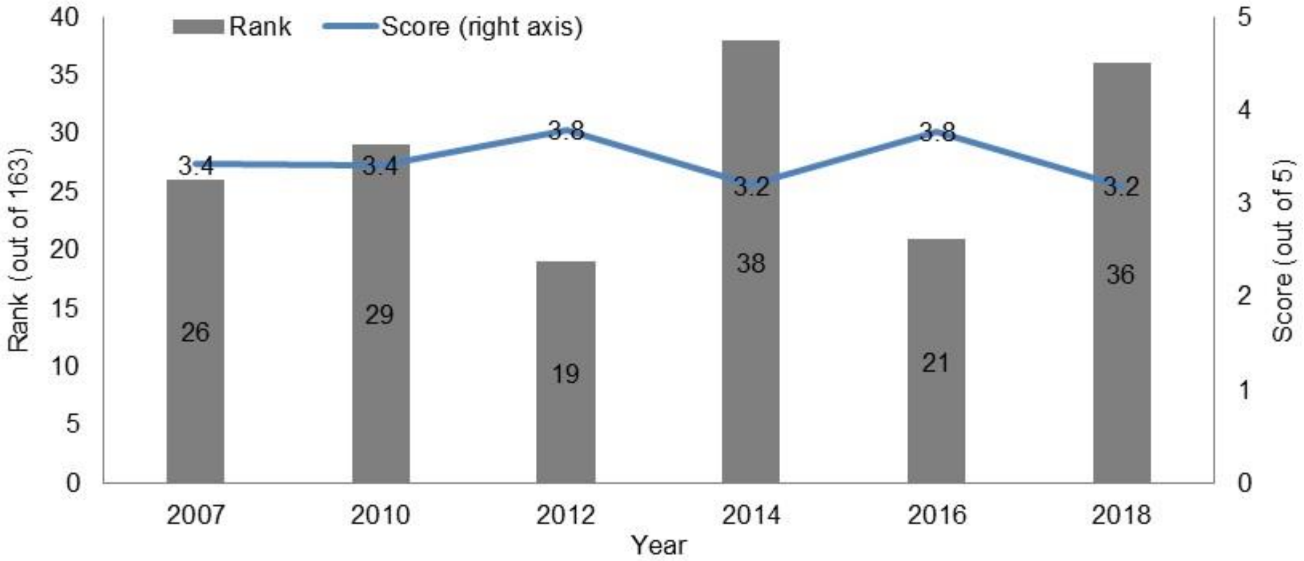
Total logistics costs in South Africa amounted to R426.0 billion in 2014, which equates to 11.2% of GDP and 51.5% of transportable GDP (Havenga *et al.*, 2016). The level of logistics costs was steady between 2003 and 2014, ranging from 13.6% to 11.0% of GDP, which is in line with international norms. But the contribution of transport to total logistics cost, shown in Figure 2.7 at 57.0% in 2014, is significantly higher than the 2013 global average of 39.0% (CSIR, 2013). Road transport comprised 83.0% of the R244 billion transport cost in 2014.

Figure 2.7: Trends in the components of logistics costs in South Africa

Source: Havenga *et al.*, 2016.

The World Economic Forum's Logistics Performance Index gives a measure of the efficiency of international supply chains. Despite the high cost of road transport as a proportion of total logistics costs, South Africa still achieved an overall rank of 34 out of 163 countries in 2014. This overall rank, however, was lowered by the quality of the transport infrastructure which is shown in Figure 2.8 to have been ranked at 38th in 2014. The same is true for 2018, where the quality of transport infrastructure was ranked 36th compared to an overall ranking of 33. All things remaining the same an improvement in the quality of transport infrastructure, which was scored in 2018 at 3.2 out of 5.0, would serve to raise the country's logistics performance.

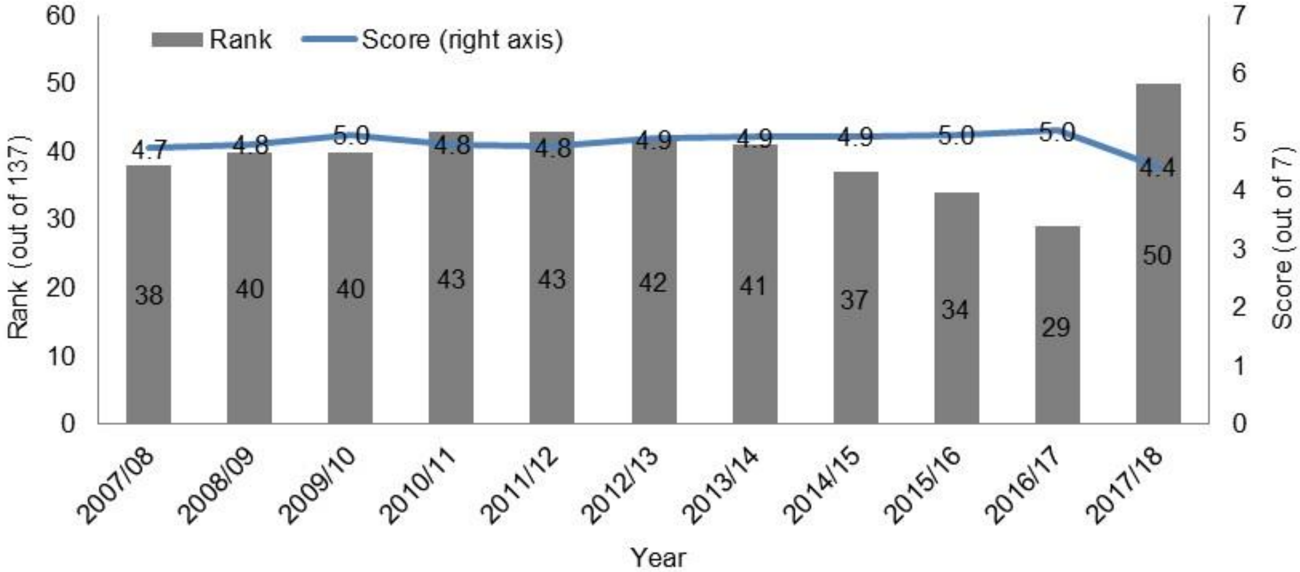
Figure 2.8: Quality of transport infrastructure as reported in the Logistics Performance Index



Source: World Bank, 2018b.

Road infrastructure quality is also a central consideration in the World Economic Forum's Global Competitiveness Index, which assesses the competitiveness of national economies. The significance of this road quality indicator is heightened by the relative transport intensity of the South Africa economy and the heavy reliance on road transport. Figure 2.9 shows that the quality of roads in South Africa was scored at 4.4 in 2017/18, with a score of 7 being the best. This score was lower than the 5.0 scored in 2016/17 and ranked the quality of the South African network 50 out of 137 countries. Downward revisions to the score assigned to the quality of roads, as experienced by South Africa in 2017/18, has a negative effect on the competitiveness of the economy.

Figure 2.9: Quality of roads as reported in the Global Competitiveness Index



Source: World Bank, 2017.

2.3.1 The decline of the rail sector

Rail is often the most cost-effective and therefore dominant transport mode for large, uniform cargoes travelling long distances. But Table 2.5 contains many examples of rail appropriate commodities that have shifted to road haulage: grains, fuels, coal, steel, cement, vehicles, and containers. To understand this situation, it is important to firstly note that development of road freight transport in South Africa was initially restricted by the Road Transport Act that was introduced in the 1930s to develop the rail network (National Department of Transport, 2018a). But reconstitution of the South African Railways and Harbours as the South African Transport Services in 1981 introduced a greater degree of commercialisation into the rail sector (DBSA, 2012). This move was followed by deregulation of the road freight industry through the Transport Deregulation Act of 1988 (National Department of Transport, 2018). Then in the 1990s the road industry negotiated an increase in the allowed vehicle-carrying capacity. This series of events, in conjunction with the development of high-speed national and provincial roads parallel to or near railway lines, placed the road freight industry in a strong position to compete with long-haul railway services.

The subsequent growth in road freight's market share had a significant negative effect on the utilisation rate of rail and the profitability of branch railway lines. This in turn led to lower investment in track infrastructure, stations, and yards and ultimately to the closure of many branch railway lines (Mitchell, 2014). The 2017 SAICE (2017) Infrastructure Report Card for South Africa notes that only 3 928 km of the 7 278 km of branch lines are operational. SAICE therefore scored the branch lines a “D-” (at risk of failure) due to the lack of provision of rail services, inadequate maintenance, and insufficient investment in supporting infrastructure.

The 139 billion tonne-km of freight transported by rail in 2014 consisted mainly of minerals and primary and secondary commodities for which rail has maintained its competitive advantage over road transport (Havenga *et al.*, 2016). Otherwise roads are the dominant transport mode for high-value commodities, general freight, and other heavy goods. Table 2.6 outlines key factors that have contributed to the downward trend in the competitiveness of rail freight in South Africa.

Table 2.6: Factors affecting the efficiency of freight rail in South Africa

Factor	**Explanation**
Reduced accessibility	Many rail stations closed in the 1980s and 1990s because of the expansion in the road freight industry. Siding to siding rail transport generally requires more than 10 wagons in a consignment (approximately 400 tonnes per consignment), which is too large for most farmers and small businesses. This has shifted large volumes of goods and long-distance cargo to roads.
Safety and damage	The cost to meet railway packaging requirements is higher than road haulage. Rail also has a double-handling cost from road to rail and back to road for delivery. These higher costs for rail are aggravated by the high incidences of derailment, collisions, and criminal actions such as cable theft and vandalism.
Reliability	The competitiveness of rail transport is negatively affected by the erratic provision of empty wagons and unreliability of delivery schedules.
Total transport time	Travel speed and the timing of delivery is key for specific loads, such as containers to meet ship stack schedules and when payment is released following delivery. The slow speed rail transport in South Africa makes roads the preferred mode of freight for most of these goods.
Costs, rates, and tariffs	Railway tariff increases have exceeded the rate of increases for road transport. The rates for many bulk commodities well suited to rail haulage - such as steel, fertiliser, cement, maize, timber, containers, and fuel - are presently comparable to railway tariffs. This has caused many industries to shift to road transport as it additionally offers greater flexibility.

Source: National Department of Transport, 2017a.

The NDOT (2017a) has responded to the skewed intermodal freight split by developing the National Rail Policy, which aims to position rail to collaborate with and compete against the other transport modes and thereby become the national land transport backbone by 2050. The NDOT's intention is that the full suite of investments and institutional interventions, of which the high-level achievements are outlined in Table 2.7, will be completed by 2050. The objective, based on details from the 2011 Road Freight Strategy, is to shift 80.0% of large, uniform, containerised freight back to rail, with roads remaining the preferred mode for only time-sensitive goods requiring high levels of flexibility. But the historical monopolistic freight rail market structure and Transnet's inability to plan according to a competitive multi-operator environment means that this modelled road-to-rail shift is uncertain, and the predetermined modal split is not driven by the relative competitiveness of road and rail transport (National Department of Transport, 2017a). Only after the standard-gauge national rail network and third-party train operators are established will the true size of the rail market and efficient modal split between road and rail become known.

Table 2.7: National Rail Policy timeline

Year	Achievement
2019	National Rail Policy enacted
2021	Accounting separation of Transnet Freight Rail Infrastructure Manager and Train Operator
2021	Regulated third party access to the freight rail market commences
2022	National Rail Master Plan completed
2022	Local authorities complete planning for additional urban guided transit corridors
2024	Construction of short lead time projects commences, followed by longer lead time projects
2025	Devolution and assignment of urban guided transit to local authorities completed
2032	Earliest operating commencement date for Gauteng–eThekwini high speed trains
2032	Earliest operating commencement date for regional rapid transit trains
2032	Earliest operating commencement date for additional urban guided transit corridors
2037	Gauteng to Cape Town, Nelson Mandela and eThekwini standard gauge sectors completed
2049	Latest operating commencement date for Gauteng–eThekwini high speed trains
2050	All other rail revitalisation projects completed

Source: National Department of Transport, 2017a.

Assuming that the planned target dates in Table 2.7 are met, the transition period is still set over a 30-year period with annual targets as low as a 2.0% shift of rail-friendly cargo from roads back to rail. Given the extended timeframe of the National Rail Policy, the relatively long lifespan of road infrastructure (generally 20 years for a sealed road), and the high levels of private sector investment in roads-based logistics it is expected that road transport will continue to dominate freight over at least the medium to long term. The NDOT (2016) seems to support this expectation through its forecasts in the National Transport Master Plan 2050 that demand on national and provincial road networks, which are the primary freight routes, will still grow by 67.0% by 2030 and 150.0% by 2050.

In addition, the NDOT (2017a) alludes to several pressures on the achievement dates set in the National Rail Policy. Firstly, it is uncertain whether parliament will timeously finalise the legislative process and that the National Rail Master Plan will be completed within three years thereafter. These events potentially push outwards the commencement date for both the short and long lead time rail projects. Secondly, greenfield projects generally have a 10-15-year project cycle, but this can be extended if the projects are associated with land acquisition and environmental impact issues. Thirdly, the National Rail Policy devolves the mandate to invest in rail infrastructure to the national, provincial, and local governments according to the same criteria as other land transport infrastructure within their jurisdictions. But a significant depth of skills and competencies must first be developed, especially within local governments, for this strategy to be successful. Lastly, international experience shows that national gauge-change projects take around 25 years to complete. But this timeframe may be negatively affected in South Africa by the rate at which the state and investors can supply the requisite funds and the capacity within the construction industry to deliver the constituent projects. Amongst other uncertainties, these pressures entrench the long-term importance of road infrastructure to economic growth in South Africa.

2.3.2 Improvements in road transport efficiency and competitiveness

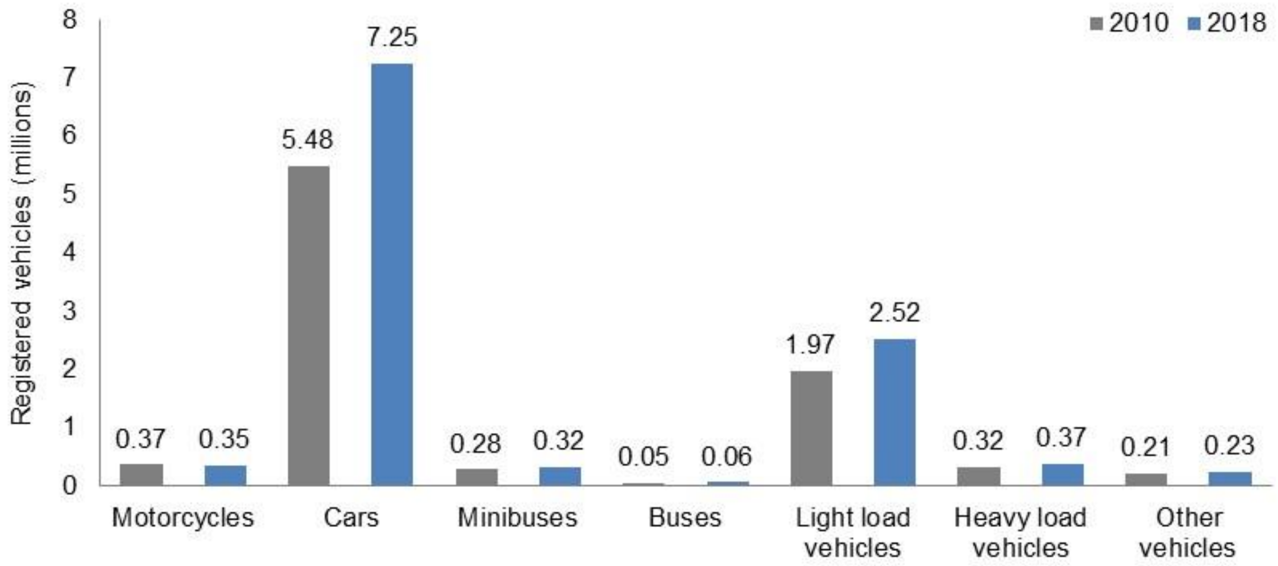
The roads sector is simultaneously evolving as these railway developments are planned to take place. The NDOT (2017a) highlight three technology trends that truck manufacturers are developing to compete with rail to maintain and even grow the sector’s market share: Highway Pilot automates a vehicle’s steering, speed modulation, and braking; Platooning remotely links multiple highway pilot trucks to minimise inter-truck gaps; and overhead electric traction boosts the sector’s environmental sustainability. These autonomous truck and smart highway technologies, amongst other developments, are predicted to significantly reduce road transport costs, enhance service quality, and increase road capacity. The potential effect of these advances is to erode the relative advantage of rail's large-scale command and control systems and thus curtail the NDOT's efforts to shift large volumes of road cargo back to rail. With such changes in mind, the NDOT (2016) forecast as part of the National Transport Master Plan 2050 that the number of registered heavy load vehicles will increase from 373 832 in May 2018 to over 1.0 million by 2050.

Stakeholders from the Centre for Scientific and Industrial Research (CSIR), government, industry, and academia have been running a Smart Truck pilot project since 2004 to trial the introduction of high productivity road freight transport. The project allows transport operators to implement innovative heavy vehicle designs and is regulated by a Performance-Based Standards (PBS) framework (National Department of Transport, 2017c). By 2018 the project included 245 demonstration vehicles in 10 industries and had collected over 100 million km of data. Amongst the observed benefits of the project are a 12.0% reduction in fuel use and emissions, 13.0% reduction in road wear, 39.0% reduction in road crashes, and 22.0% less truck kms travelled (National Department of Transport, 2017c). This project provides another example of how road transport may either continue to dominate rail or alternatively remain competitive with rail should the NDOT achieve the goals set out in the National Rail Policy.

2.4 PASSENGER DEMAND FOR ROAD TRANSPORT

There is also a significant level of passenger demand for road transport, and therefore road infrastructure, in South Africa. Figure 2.10 indicates that the population of registered vehicles reached 11.1 million in May 2018, 28.2% higher than in 2010 when the consolidated records began (eNaTiS, 2010; eNaTis, 2018). Whilst the population in all vehicle classes except motorcycles increased over this period, the growth was largely driven by an additional 1.8 million cars and 0.6 million light load vehicles. There was also notable growth in the number of minibuses and buses, which are linked with the demand for public transport.

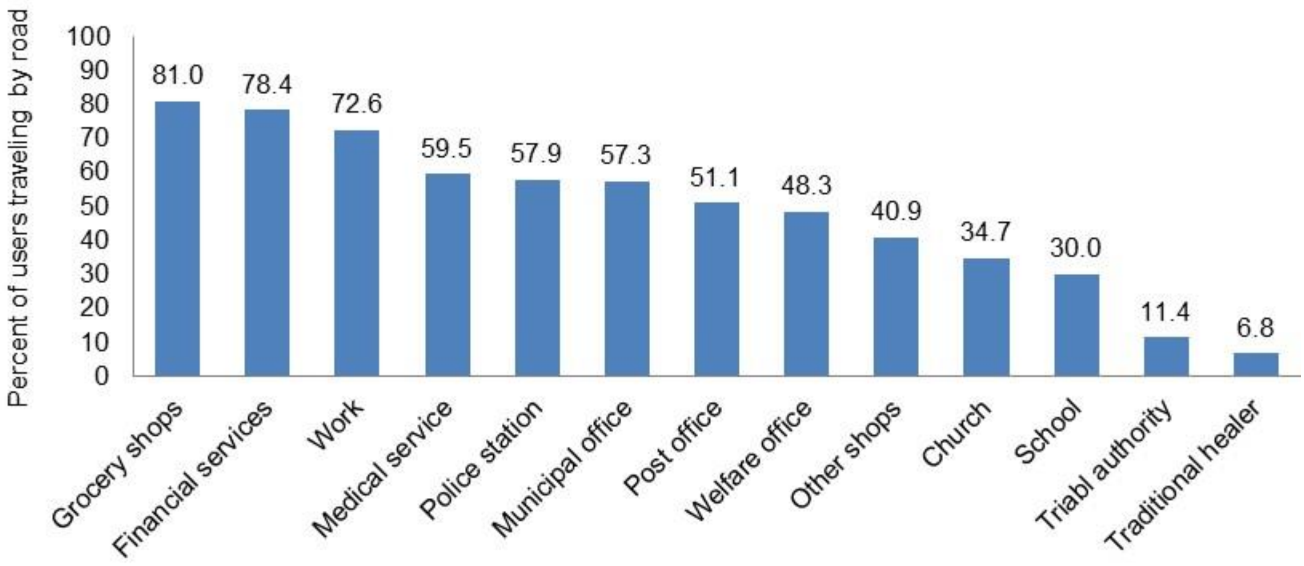
Figure 2.10: The trend in registered vehicles



Source: eNaTiS, 2010; eNaTis, 2018.

Another indication of the level of passenger demand for road infrastructure is seen through the number of citizens who access services using road transport. Figure 2.11 uses Statistics South Africa's (2014) 2013 National Household Transport Survey to rank places according to the proportion of citizens' who rely on roads to access that service or facility. The heavy reliance on road transport to access points of interest brought transport costs up to 15.3% of total household consumption expenditure in 2017 (South African Reserve Bank, 2018).

Figure 2.11: Population accessing services using road transport, 2013



Source: Statistics South Africa, 2013.

2.5 CONCLUSION

Road infrastructure is South Africa's single largest public asset. While a certain level of wear and consumption of capital assets is acceptable, the road network has deteriorated from its current replacement cost of R3.3 trillion to R1.4 trillion. Despite this deterioration in condition the road network currently supports over 11.1 million vehicles and facilitates roughly two-thirds of the total land freight flow. The road network is thus fundamental to economic growth. This relative economic importance of road infrastructure is set to continue over the medium to long term even if the National Rail Policy can be successfully implemented. But it is likely that possible setbacks to the National Rail Policy in conjunction with developments in the road transport sector will increase, or at least maintain, the competitiveness of road freight and passenger services. A significant proportion of local and traded goods and transport users are therefore affected by the level and standard of road infrastructure investment.

3 THE ECONOMIC BENEFITS OF ROAD INFRASTRUCTURE INVESTMENT

Given the relatively heavy reliance of the South African economy on road infrastructure, it is important to understand the mechanisms through which road infrastructure investment can support growth. The World Bank (1994) recognises that infrastructure, “if not the engine”, is the “wheels of economic activity”. World Bank supported road projects between 1974-1982 and 1983-1992 yielded respective average economic rates of return of 20.0% and 29.0%. These rates of return, which were the highest amongst 13 types of infrastructure, indicate the high potential growth payoff of investment in road infrastructure. We are reminded of Adam Smith’s (1776) words: “Good roads, canals, and navigable rivers, by diminishing the expense of carriage, put the remote parts of the country more nearly upon a level with those in the neighboring town. They are upon that account the greatest of all improvements”. To help ensure that the South African road authorities are able to maximise the growth potential of their road infrastructure investments, bearing in mind that road projects do not necessarily generate a positive economic return, this chapter explores the direct and indirect effects of road infrastructure on growth from theoretical, international, and local perspectives.

Section 3.1 contextualises this review within South Africa’s prevailing economic and policy environment. The economy is currently in a tenuous situation with the National Development Plan (NDP) expressing concern that South Africa has fallen into a low-growth middle-income trap, where growth has stagnated at middle-income levels rather than describing a path to a high-income country (National Planning Commission, 2012). Considering this concern and the currently weak state of the domestic drivers of growth, the NDP has opted to pursue an exports-led growth strategy. The government’s expectation is that increased investment rates will initially be achieved through public spending on infrastructure that crowds in private investment by improving efficiency in the economy and reducing costs for businesses and individuals. Road infrastructure investment is therefore central to the NDP growth strategy given that road transport, amongst other contributions, facilitated 61.1% of total land freight flows and 85.0% of general freight in 2014 and 72.6% of travel to work in 2013.

Section 3.2 applies economic growth theory as the framework to assess the potential growth contributions of road infrastructure investment. Road maintenance activities are included in the scope of road infrastructure investment as the effects of a road may be diminished, or become indiscernible or negative, if the road is not appropriately maintained. Howe (2001) demonstrates that in the extreme case of inadequate maintenance the only effects of road investment that are likely to remain over the long-term are the dis-benefits embedded in the original investment, for example the land lost to the right-of-way for a road that cannot be used for other purposes. The preconditions for growth, such as the complementarities of a road investment and the extent to which pre-existing and post-investment road infrastructure supply matches the demand, are also addressed given that road infrastructure investment is an insufficient condition for growth and risks crowding-out private investment.

Section 3.3 explores the direct effects of road infrastructure investment on the productivity of private inputs and the rate of return on private capital. The potential for road infrastructure investment to increase the marginal productivity of private inputs in South Africa and thereby raise the perceived rate of return of private capital is linked with two variables: the transport dependence of the associated sectors, which is shown to be relatively high; and the initial stock of road infrastructure, which although relatively well-developed is heavily deteriorated and hence partly responsible for inflated logistics costs.

Section 3.4 explores the following set of indirect effects of road infrastructure investment on growth: productivity of other inputs; private capital maintenance and durability; the volume of marketable products; public capital durability; road accidents; adjustment costs; inventory costs; human capital formation; economies of scale and scope; agricultural output; rural income and rural-urban migration rates; land values; utilisation and skills of underemployed and unemployed workers; regional integration and trade; and road investment policy as a form of industrial policy.

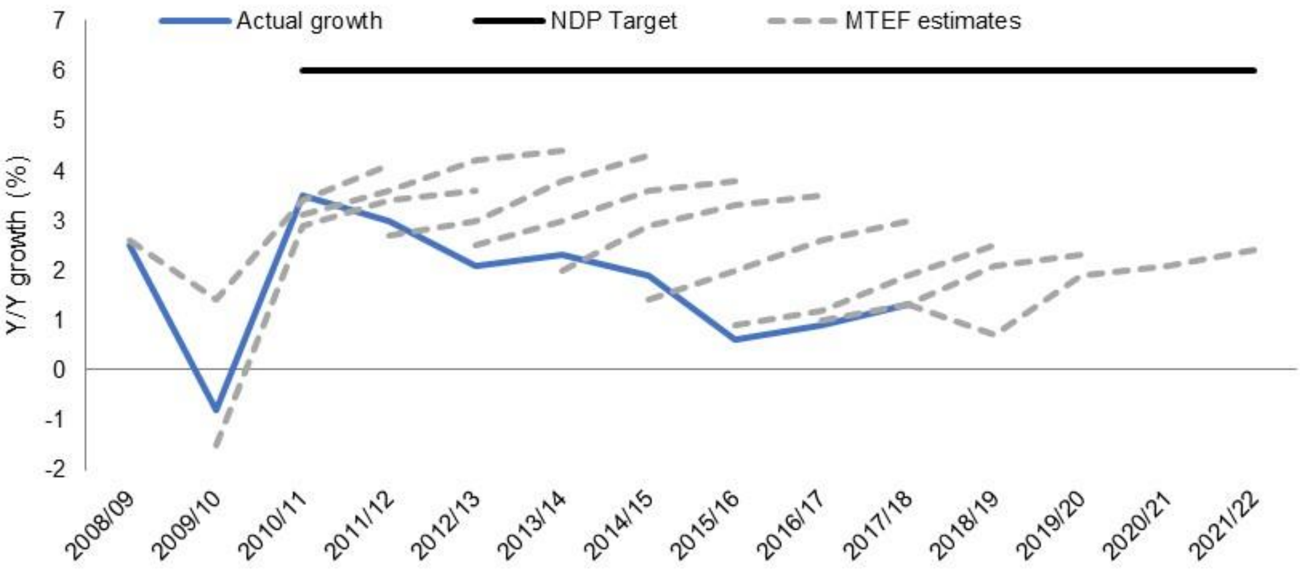
Section 3.5 concludes by emphasising the importance of road infrastructure investment if South Africa is to address some of the structural challenges that have led the economy into the low-growth middle-income trap and to achieve the growth targets set by the NDP. While road infrastructure investment is necessary to achieve these objectives, the road investment policy must be carefully planned as inefficient investment decisions by any of the national, provincial, and municipal road authorities risk negative economic consequences.

3.1 NATIONAL DEVELOPMENT OBJECTIVES

The 2018 Draft Integrated Planning Framework Bill sets the NDP as the country's official planning document (Department of Planning, Monitoring and Evaluation, 2018). The NDP stresses the concern that the South African economy displays the features of a low-growth middle-income trap, which is characterised by four features: a lack of competition; low savings; large numbers of work seekers who cannot enter the labour market; and a poor skills profile (National Planning Commission, 2012).

Figure 3.1 details the economic growth outcomes following the 2007 financial crisis. Annual growth has declined since reaching 3.5% in 2010/11, with the outcomes significantly below the 6.0% (or average of 5.0%) targeted by the NDP and below the National Treasury's MTEF estimates. Given annual population growth of approximately 1.5% and the fact that public expenditure is being funded through debt, economic growth notably less than the NDP target means that per capita wealth is falling, or at best staying constant, and the government will struggle to cover its debt service costs which are estimated to increase from 3.4% of GDP in 2017/18 to 3.9% of GDP in 2021/22 (National Treasury, 2018e).

Figure 3.1: Revisions to real GDP growth forecast



Source: National Treasury, 2018e.

Moreover, unresolved domestic constraints led fixed-capital formation to decline in 2017 and unemployment to grow to 27.7% in 2017Q3, its highest level since 2003 (National Treasury, 2018d). Investment spending in South Africa declined from an average of nearly 30.0% of GDP in the early 1980s to roughly 16.0% of GDP by the early 2000s, recovering slightly to 19.5% of GDP in 2016 (National Treasury, 2018d). The NDP notes that these low investment levels have resulted in a missed generation of capital investment in transport infrastructure (National Planning Commission, 2012). To realise a sustained impact on economic growth, the NDP states that gross fixed-capital formation needs to reach 30.0% of GDP by 2030, with public sector investment comprising one-third of this amount.

The NDP presents the following factors as structural barriers to higher levels of investment, employment, and growth: too few people work; infrastructure is poorly located, inadequate and under-maintained; the economy is too resource intensive; the quality of schooling is poor for Black people; spatial divides hobble inclusive development; the public health system cannot meet demand or sustain quality; public services are uneven and often of poor quality; corruption levels are high; and society remains divided (National Planning Commission, 2012). The NDP proposes several measures, including road infrastructure investment, to address these growth constraints through enhanced human capital and export capacity.

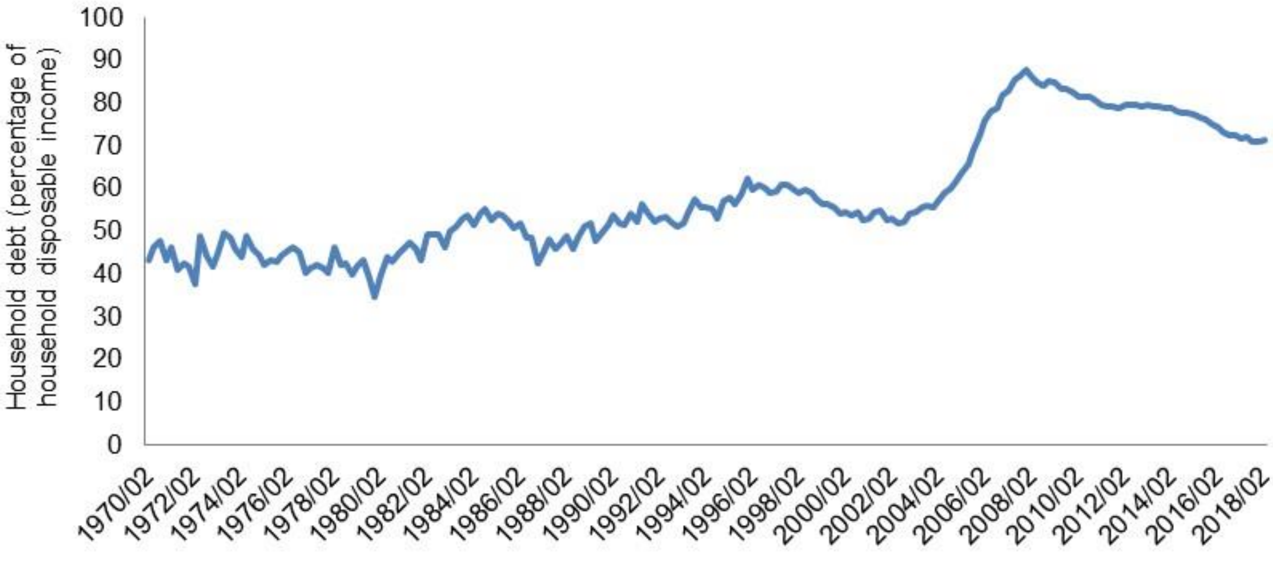
3.1.1 <u>Exports-led growth strategy</u>

Loosely following examples set by the outward-orientated strategies adopted by the Asian Tigers, exports-led growth is promoted by South African government policies including the NDP, the New Growth Path, and Industrial Policy Action Plan. These planning documents emphasise export expansion based on the following direct and indirect benefits that accrue to exporting: exports are a component of GDP and therefore have a direct causal impact on GDP (Little *et al*., 1970; Krueger, 1978); export growth extends potential demand from the relatively small domestic market to include foreign markets and thus triggers higher levels of production, investment, and growth (Ibarra, 2010; Weiss, 2005; Ye *et al*., 2010); export growth can create economies of scale that in turn improve total factor productivity (Helpman and Krugman, 1985; De Melo and Robinson, 1990; He and Zhang, 2008); export production generates foreign exchange earnings to service foreign debts and to facilitate imports, including productivity enhancing capital goods (McKinnon, 1964; Weiss, 2005; Jin, 1995); the international competition from export exposure pressures local firms to be more efficient, with Clarke *et al*. (2007) finding that South African firms that export at least 37.0% of their output are 22.0% to 24.0% more productive than firms that export no output (Balassa, 1978; Krueger, 1980); interactions with foreign businesses and markets facilitates knowledge and skills transfers (Grossman and Helpman, 1991); and exports can enhance specialisation in local sectors with global comparative advantages, which promotes reallocation of resources from non-tradable sectors to tradable sectors (Salvatore, 2011; Mahadevan, 2007).

There is a large body of international literature that supports an exports-led growth strategy, including: Balassa (1978, 1985); Tyler (1981); Feder (1982); Ram (1987); Chow (1987); Giles *et al*. (1992); Thornton (1996); Xu (1996); Doyle (1998); Erfani (1999); Balaguer and Manuel (2004); Shirazi and Abdul Manap (2005); Jordaan and Eita (2007); and Saad (2012). Studies that verify the exports-led growth hypothesis for South Africa include Rangasamy (2009), Ziramba (2011), Cipamba Wa Cipamba (2013), and Ajmi *et al.* (2015).

A brief review of the domestic drivers of growth in South Africa confirms the relevance and necessity for an exports-led growth strategy. Household spending generally accounts for approximately 60.0% of GDP, but consumer demand has become limited by the build-up of household debt illustrated in Figure 3.2. While household debt fell from a high of 87.8% of household disposable income in 2008Q1 to 71.3% in 2018Q2, consumer demand for credit is expected to remain weak until households have consolidated their debt positions.

Figure 3.2: Household debt, 1970Q2 – 2018Q2

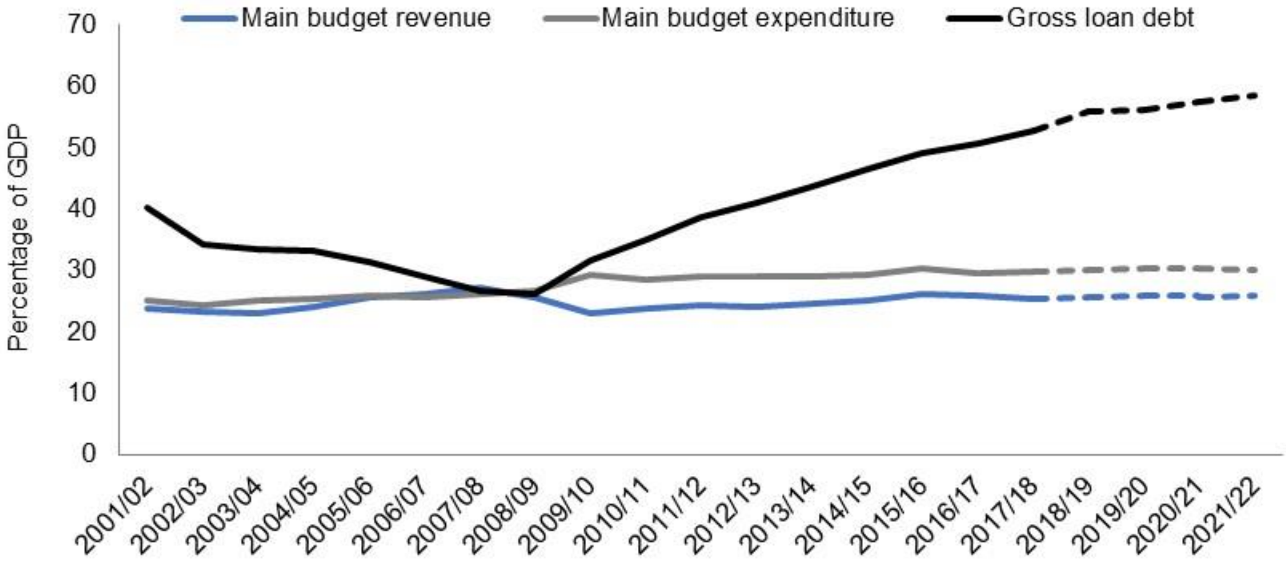


Source: Statistics South Africa, 2018b.

The National Credit Regulator (2018) reported that in 2017Q4 15.6 million consumers were in good credit standing and 9.7 million consumers had impaired records. Total consumer credit had grown to R1.8 trillion by 2017Q4, with unsecured credit accounting for 9.7% of this gross debtors book. The World Bank (2018b) Global Findex Database 2017 reveals that South African consumers are amongst the most stretched globally, with only 29.0% reporting it would be possible to raise additional funds in the case of an emergency. This information suggests there is little room at present for household consumption to support a meaningful economic recovery in South Africa and sustain the 6.0% annual growth targeted by the NDP.

Moreover, government expenditure is an increasingly strained source of economic stimulus in South Africa. Figure 3.3 shows the consistently poor performance of main budget revenue since 2008/09 and the resultant upward pressure on gross loan debt. The National Treasury (2010) first expressed a commitment to fiscal consolidation in the 2010 Medium-term Budget Policy Statement (MTBPS), with this policy reinforced in subsequent Budget Reviews and MTBPSs. This commitment is regularly monitored by the ratings agencies with concerns expressed over the rising level of gross loan debt. Given the persistently low main budget revenue collections, the primary mechanism through which the National Treasury intends to consolidate gross loan debt is capped public expenditure. While the imposed expenditure ceiling helps to protect debt sustainability and credit ratings, it limits government's ability to stimulate growth through public spending.

Figure 3.3: Government revenue, expenditure, and debt, 2001/02 – 2021/22



Source: National Treasury, 2018e.

In contrast to South Africa, which was just shown to have a relatively small domestic market that is presently characterised by indebted consumers and fiscally constrained government, the international economic conditions have recently improved. In fact, global growth reached a 4-year high of 3.7% in 2017 (National Treasury, 2018e). By 2019 global growth is expected to remain at 3.7%, with average growth of 2.1% among advanced economies, 4.7% among developing economies, and 3.8% among Sub-Saharan African countries.

South African businesses should be enabled to exploit the export development opportunities presented by the positive global outlook and the relatively competitive exchange rates of the rand to grow the country's production base. Total exports of goods and services contributed 29.3% to GDP in 2017, with the Industrial Development Corporation (IDC) (2017) noting that the country's export base is spread across multiple sectors (South African Reserve Bank, 2018). South Africa's major export sectors, where exports contributed more than 45.0% of sectoral output in 2016, include: mining; non-ferrous metal products; motor vehicles, parts and accessories; machinery and equipment; basic iron and steel; rubber products; and television, radio and communication equipment (Industrial Development Corporation, 2017). Road infrastructure investment must therefore efficiently support a cross-section of export related sectors to allow local businesses to maximise export potential.

The NDP also demands that infrastructure investment must support employment and labour-intensive industries (National Planning Commission, 2012). The IDC (2017) estimated that in 2016 1.2 million jobs, or 10.0% of total employment, were directly related to exports. When linkages between export production and local input suppliers are considered this estimate increases to 2.5 million jobs, or 21.4% of total employment. For example, exports of locally manufactured motor vehicles, parts and accessories sustain production in multiple supplier industries such as: machinery and equipment; fabricated metal products; rubber; plastic products; leather products; electronics; platinum group metals; transport services; and a range of business services. Table 3.1 disaggregates formal sector employment associated with South African exports. The highest number of export related jobs are in the services sector, while the radio, TV, instruments, watches, and clocks sector has the largest proportion of export related employment at 77.4%. To realise the NDP growth targets, road infrastructure investment must efficiently support the labour-intensive export industries with comparative advantages and a relatively high depth and breadth of domestic linkages.

Table 3.1: Formal sector employment associated with South Africa's exports, 2016

Sector	Export related jobs	
	Number of jobs	% of sector employment
Agriculture, forestry and fishing	369 632	42.3%
Mining	343 945	75.2%
Food, beverages and tobacco	48 982	20.0%
Textiles, clothing and leather goods	33 123	36.0%
Wood and paper; publishing and printing	46 469	34.5%
Petroleum products, chemicals, rubber and plastic	71 191	45.9%
Other non-metal mineral products	14 944	26.5%
Metals, metal products, machinery and equipment	187 135	72.1%
Electrical machinery and apparatus	16 166	36.4%
Radio, TV, instruments, watches and clocks	14 237	77.4%
Transport equipment	73 994	66.8%
Furniture and other manufacturing	20 768	30.1%
Services sectors (including government)	1 285 479	13.8%
Total	**2 526 065**	**21.4%**

Source: Industrial Development Corporation, 2017.

3.2 ECONOMIC GROWTH THEORY

Given South Africa's exports-led growth strategy and NDP targets, economic growth theory is applied as a framework to assess the potential contributions made by road infrastructure investment to economic growth. A similar approach has been followed by, amongst others, Straub (2008), Agénor and Moreno-Dodson (2006), Agénor (2004), and Aghion and Howitt (1998). The effects are represented in reduced form by the following aggregate production function, which can be framed either in terms of quantities or quality of road infrastructure:

$$Q = A(\theta, KI).f(K, L, G(KI)) \qquad 3.1$$

where Q is real aggregate output, K is non-infrastructure capital stock, KI is infrastructure capital stock (which includes road infrastructure), L is aggregate hours worked by the labour force, and $A(.)$ a standard productivity term. KI enters the production function $f(.)$ through a function $G(KI)$.

Following the assumption that the stock of infrastructure has pure public good attributes and produces services in a non-rival and non-excludable way, infrastructure can be captured in this formulation of the production function as an additional factor of production *(G(KI)=KI)*. But this assumption is unrealistic as some infrastructure investment is mediated through markets and characterised as a private good, and secondly, even when private operators are involved, factors such as price regulation mean that service charges are often not market determined (Straub, 2008). So rather than an additional production factor, infrastructure *KI* enters the production function through the service provided by this capital *(G(KI)=I(KI))*. *I(KI)* is an intermediate input variable, which better reflects the nature of roads. An increase in *KI* would lower the cost of related intermediate inputs, such as road transport, that enter firms' production functions. Whether an additional factor of production or an intermediate input variable, *G(KI)* captures the "direct" effects of road infrastructure discussed in Section 3.3.

This formulation of the production function distinguishes between two sources of increases in the productivity parameter *A*: generic efficiency-enhancing externalities represented by θ, and efficiency-enhancing externalities from the accumulation of infrastructure capital stock (Straub, 2008). The efficiency-enhancing externalities are referred to as the "indirect" effects of road infrastructure, which are individually explored in Section 3.4.

This formulation of the aggregate production function makes no assumption on the nature of returns to scale. The elasticity of infrastructure introduced as part of the *f(.)* function and the strength of potential externalities determine whether road infrastructure investment will generate diminishing, constant, or increasing returns. Sections 3.3 and 3.4 draw on a range of international and local studies and illustrative data to explore whether road infrastructure investment, through its direct and indirect effects on aggregate production, is likely to simply act as a capital accumulation device or whether it has the potential to foster endogenous growth processes in South Africa.

3.2.1 Preconditions for economic growth

Road infrastructure investment is an insufficient condition for economic growth. The growth impact depends on the complementarities of a road investment and the extent to which pre-existing and post-investment road infrastructure supply matches the demand. The channels in Equation 3.1 generally yield a positive relationship between road infrastructure investment and economic growth, but as proven in 4 of the 64 road transport studies reviewed by Straub (2008) it can also have a negative effect on growth. These negative growth outcomes occur when: life-cycle road construction and maintenance costs exceed a road's contribution to growth; road infrastructure investment disproportionately crowds out private investment; or insufficient road infrastructure investment increases vehicle operating costs, reduces the life-span of public and private capital, decreases labour productivity, imposes private capital adjustment costs, or hinders human capital development. Klevchuck and Jenkins (2004) cite 3 roads in Limpopo where a combination of low demand and few or weak complementarities yielded a negative economic return despite a supposed connection to key economic sectors. There are likely many more examples across the South African road network.

For a road infrastructure investment to promote rather than impede economic growth the social return from the infrastructure investment must be greater than the opportunity cost of the funds used to finance the investment. Based on the economic cost of borrowing from the capital market, the opportunity cost of funds to finance a road investment are a weighted average of: the gross of tax foregone return from the private investment that is crowded out; the opportunity of consumption that is postponed; and the marginal cost of any funds that are induced into the country to assist in the financing of infrastructure investment.

Accordingly, an increase in the stock of road infrastructure may adversely affect economic growth to the extent that it crowds-out private investment. As Fedderke and Bogetic (2009) explain, under a Barrow style endogenous growth model with a balanced budget constraint the growth rate falls when taxes are used to fund public infrastructure (known as the tax effect) and rises through the effect of the public infrastructure investment on the marginal product of private capital (known as the capital productivity effect). The capital productivity effect dominates at lower levels of public infrastructure provision, whereas the tax effect dominates at higher levels of provision. This indicates that road infrastructure investment can raise growth only within limits. Once the marginal product of capital has diminished to the point where the tax effect dominates, additional road investment will harm growth.

Agénor and Moreno-Dodson (2006) further explain these crowding-out effects. If the road infrastructure investment is paid for by borrowing on domestic financial markets, there may be an adverse growth effect because of higher domestic interest rates or a greater incidence of credit rationing to the private sector. And secondly, road infrastructure investment funded through a significant increase in public borrowing could raise fiscal sustainability concerns, expectations of a future increase in inflation or taxation, and the risk premium embedded in interest rates. The higher cost of borrowing and the lower expected after-tax rates of return might cause private investors to revise their investment plans downwards.

Agénor and Moreno-Dodson (2006) note that in principle the crowding-out effects of public investment in road infrastructure should only be short term. The increase in the stock of road infrastructure should raise output growth over the medium to long term, which would reduce rather than increase the government's borrowing needs. But bearing in mind that crowding-out effects may persist beyond the short term, Bryceson *et al.* (2006) note 4 preconditions for investment in rural road infrastructure to lead to economic growth: the density of the rural road network should not be fully saturated; there must be adequate provision of social and economic infrastructure; rural households must own or have access to motorized transport; and rural households must have enough money to use public transport. These preconditions are all pertinent in South Africa given the extent of the road network and high proportion of low-volume rural roads, the high rates of rural poverty, and the lack of comprehensive public transport systems. Authorities should therefore guard against poor investment decisions that either crowd out private investment or constrain growth by diverting the limited public funds from more productive investments.

3.3 DIRECT EFFECTS OF ROADS ON ECONOMIC GROWTH

Road infrastructure affects growth through direct productivity and cost effects. If the factors of production are gross complements, which is often the case, an improvement in the stock of road infrastructure might raise the productivity of the other production inputs such as labour and the stock of private capital (Agénor and Moreno-Dodson, 2006; Agénor, 2012). This in turn reduces unit production costs and helps to address the first feature of the low-growth middle-income trap, uncompetitive goods and services.

An increase in the marginal productivity of private sector inputs may raise the perceived rate of return on private sector physical capital, which is an important catalyst to crowd in private investment (Agénor and Moreno-Dodson, 2006). Referring to Hirschman's (1960) argument that savings in less developed countries depend on the investment opportunities, the direct effects from road infrastructure investment might also ease the second feature of the low-growth middle-income trap, low savings.

The magnitude of these direct effects is based on the transport dependence of associated sectors. As shown in Chapter 2 road transport is a significant input in the production process of many goods in South Africa, with almost two-thirds of land freight currently transported by road. This high intensity of road transport is boosted by the underperformance of the rail sector and the trend towards specialisation of individual functions in the production process, with many products now consisting of separate components produced at different locations. Road infrastructure investment therefore has the potential to have a strongly positive effect on the productivity of the other production inputs, and therefore growth.

Because of decreasing returns, another determinant of the magnitude of these direct effects is the initial stock of road infrastructure (Agénor and Moreno-Dodson, 2006; Agénor, 2012). The relatively high stock of road infrastructure in South Africa, which is the 10th longest road network globally, may depress the effect of road construction projects on growth unless new roads connect previously isolated area. Despite the extent of the network, the effects should be strong for road maintenance given the negative impact that deteriorated road conditions have had on transport costs, with Chapter 2 showing that transport costs in South Africa are double the global average when measured as a proportion of total logistics costs. The NDP acknowledges this by noting that poor transport links have raised the cost of doing business and are hobbling trade and investment (National Planning Commission, 2012).

Many international studies show the direct productivity and cost effects of road infrastructure investment. For example, road infrastructure investment in the Philippines reduced transport costs for the associated commercial enterprises by 54.0% and led these enterprises to grow by an average of 113.0% for two years following the road project (USAID, 1978). Moreover, the improvement of National Highway No.5 in Vietnam in the early 1990s led to significant investment in industrial zones that spurred growth and employment (Mitsui, 2004). However, insufficient road infrastructure investment puts upward pressure on transport costs that is detrimental to the competitiveness of goods and services and ultimately private investment. Escribano *et al.* (2008) argue insufficient road networks, in addition to other infrastructure deficits, depress firm productivity by up to 40.0% in many sub-Saharan African countries.

3.4 INDIRECT EFFECTS OF ROADS ON ECONOMIC GROWTH

Road infrastructure also affects growth through indirect effects. When analysing the various indirect effects care must be taken to avoid double-counting, as the value of many of these effects have been measured in some other way. Many of the indirect benefits that arise from road investments represent the allocation of the benefits from lower travel costs across the project stakeholders, for example savings in vehicle operating costs and time from a road investment are often capitalised into the market value of land. The indirect externalities that are excluded from a traditional willingness to pay study for a road project are the affects to public capital durability, human capital formation, agglomeration economies, the utilisation of underemployed and unemployed workers, and rural-urban migration rates.

3.4.1 Productivity of other inputs

Independent of its direct effects on the marginal product of factor inputs in the production process, road infrastructure investment may also have an indirect impact on total factor productivity (TFP). This impact is brought about by the efficiency with which the factors of production combine to generate growth in output. The NDP suggests that if the targeted private investment rates are not achieved, higher growth might still be sustained if there is a significant rise in capital and labour productivity (National Planning Commission, 2012).

Fedderke and Bogetic (2009) applied an endogenous growth model to assess the impact of 19 infrastructure measures on TFP in South Africa from 1970 to 1993. The total road network had a strongly positive and statistically significant impact on TFP, with a 1.0% increase in the road network associated with a 2.8 percentage point increase in productivity growth. The impact of paved roads on TFP was stronger with a 1.0% increase in the paved road network yielding a 4.9 percentage point increase in the manufacturing sector’s productivity growth. These impacts must be considered in relation to the extent of South Africa’s road network, where a 1.0% increase is associated on the margin with 7 500 km of road. But between 2008 and 2012 the provincial and municipal authorities respectively built only 90 km and 1 477 km of new roads (CSIR, 2013). The evolution of the road network since 1993, which has grown with urban expansion and local economic development objectives, may have a bearing on this estimated impact of road infrastructure investment on TFP.

Ferreira (1999), Agénor (2012), and Agénor and Neanidis (2014) argue that better access to roads means that workers can get to work more easily. Reduced commute time to work or across work locations tends to reduce traffic-related stress that harms labour productivity. In addition, the United Kingdom Department for Transport (2005) reference three sources of increased output from reduced commuting time: increased participation in the workforce; moving to a more productive higher paid job; and longer working hours. While there is strong evidence in support of increased labour participation and mobility, Abelson (2010) argues that there is insufficient evidence that a shorter commute promotes longer working hours.

Many South Africans, but mostly poorer citizens, live far from places of work because of the legacy of apartheid spatial patterns. In this context, the travel time on a very poor condition road can be 4 times longer than a good condition road (Committee of Transport Officials, 2014). Statistics South Africa's (2014) National Household Travel Survey indicates that 2.9 million workers walked and 3.9 million drove to work in 2013. The mean travel time to work was 34 minutes for those walking, 38 minutes by car, 50 minutes by taxi, and 74 minutes by bus, bearing in mind that 19.2% of those who travelled by vehicle were delayed by switches in transport mode. But 8.8%, 53.2%, 26.0%, and 14.9% of people who respectively travelled to work by foot, bus, taxi, and car spent more than an hour doing so each day.

This issue of spatial divides is compounded by the high rates of urban congestion, which COTO (2014) attribute to insufficient road capacity along with inefficient public transport and capacity management. The 2013 TomTom Traffic Index reveals that peak period travel times were extended by an average of 21.0% across Johannesburg, Cape Town, East London, Pretoria, Durban and Bloemfontein (Committee of Transport Officials, 2014).

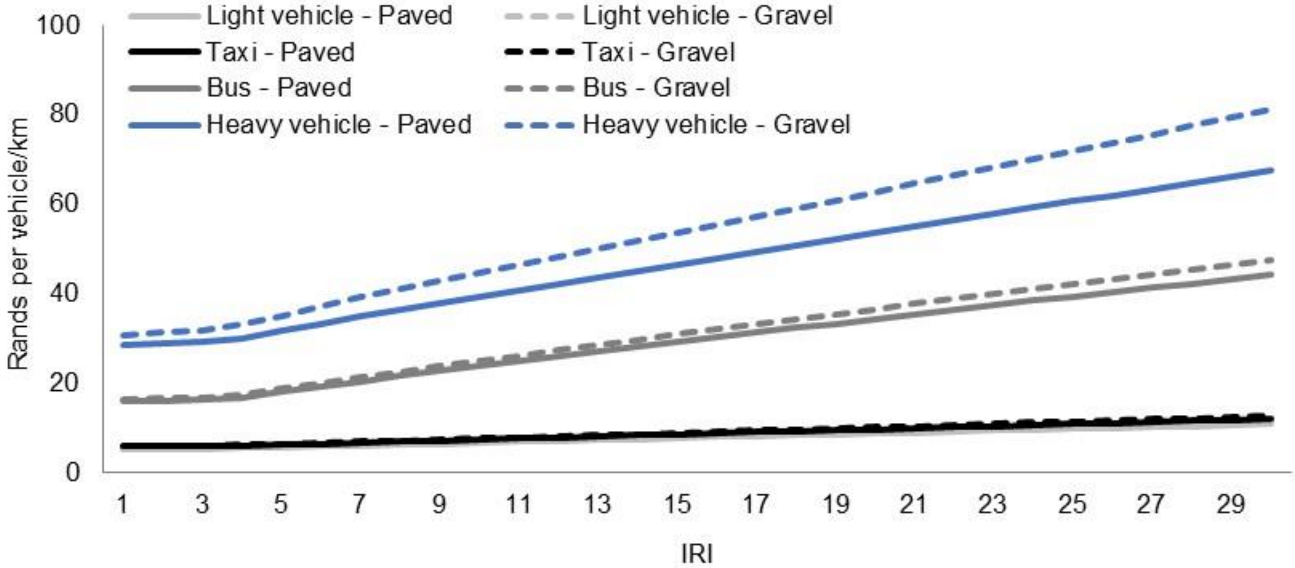
Given these transport conditions, research confirms that road infrastructure investment has had a positive effect on labour productivity in South Africa. The most noteworthy study was conducted by Fedderke and Bogetic (2009), who estimated elasticities of 2.95 for the total road network and 1.08 for paved roads. The NDP therefore calls for investment in transport infrastructure to support public transport routes and link the major concentrations of urban labour into mainstream city life (National Planning Commission, 2012).

3.4.2 Private capital maintenance and durability

The correlation between road condition and the vibrations experienced by vehicles travelling on the road means that better road conditions are typically associated with a longer duration of relevant private capital and savings in vehicle operating costs (VOC) (Straub, 2008). For example, Gyamfi and Guillermo (1996) studied the effect of deferred road maintenance on VOC in Latin America and the Caribbean and found that each dollar not spent by authorities on road maintenance resulted in an average increase of $3.0 in VOC through poorer road conditions. These effects impact logistics costs and influence real aggregate output through the global competitiveness of local goods.

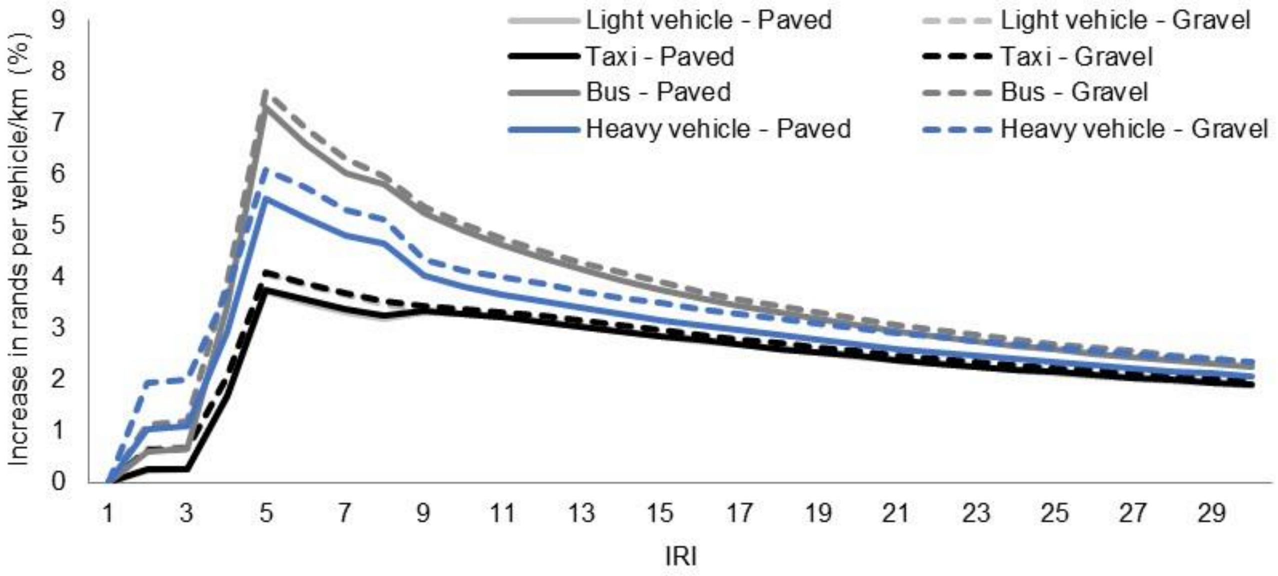
Figure 3.4 shows the relationship between VOC and the International Roughness Index (IRI) on a flat road. The relationships are similar for rolling and mountainous terrain, except the VOC are higher than for flat roads. Figure 3.5 depicts the same information in terms of the percentage increase in VOC for every 1-point increase in the IRI. The increases in VOC are highest between an IRI of 3 and 6, which reflects a shift from good to fair road condition. Increases in VOC slow between an IRI of 6 and 8, which correlates with a shift from fair to poor road condition, before tapering once a road is in very poor condition. The quality and required maintenance of the private capital stock thus depends heavily on road conditions, with good road conditions freeing private funds for investment in productive alternatives.

Figure 3.4: Vehicle operating costs on a flat road



Source: Western Cape Department of Transport and Public Works, 2018a.

Figure 3.5: Relative increase in vehicle operating costs on a flat road



Source: Western Cape Department of Transport and Public Works, 2018a.

The CSIR's (2009) 6th Annual State of Logistics Survey for South Africa presented a South African case study of the effects of road condition on vehicle maintenance and repair costs. This study reported a 121.0% increase in average maintenance and repair costs for trucks when road conditions fell from good to very poor, which in turn raised total company logistic costs by 10.0%.

While fuel consumption differs according to several factors, including topography and the weight and speed of a vehicle, a simple comparative study of truck traffic on South African highways found fuel consumption to be 15.0% higher on roads in poor versus good condition (Van Der Walt, 2011). Chatti and Zaabar (2012) found a similar result, with a 1-point increase in the IRI increasing the fuel consumption of heavy trucks by approximately 1.0% at 96 km/h and 2.0% at 56km/h. These results are corroborated by international studies, for example the World Bank (1999a) estimated that in Vietnam reducing a road's roughness from an IRI of 14 to 6 and 3 would respectively save between 12.0% to 22.0% and 17.0% to 33.0% in VOC. In terms of the relationship between road condition and tyre wear, Chatti and Zaabar (2012) estimate that at 88 km/h the tyre wear of heavy trucks is approximately 1.0% higher for every 1-point increase in the IRI.

Nordengen (2004) used standardised VOC data to estimate that actual road conditions in South Africa, which have since deteriorated further, inflated VOC for heavy vehicles by an average of 12.8% compared to an ideally maintained version of the network in which 60.0% of roads are in a good and very good condition. When this finding is applied to the 2014 national logistics data, in which road transport accounts for 83.0% of the R244.0 billion total transport costs, it suggests that suboptimal road investment inflated the annual cost of road freight by R25.9 billion (Havenga *et al.*, 2016). The implications of this finding are profoundly negative for domestic consumers as well as the competitiveness of South African exports.

3.4.3 Volume of marketable products

Straub (2008) also links a road's roughness with the volume of damaged freight. Increased vehicle vibrations from deteriorated road conditions lead to freight damages during transport (Committee of Transport Officials, 2014). Van Der Merwe (2011) found that in South Africa poor road conditions led to a 1.0% to 2.0% increase in the volume of damaged cargo. When this impact is assessed in relation to the R508.4 billion in transportable GDP moved by road in 2014, the road network deterioration could incur annual freight damage costs between R5.1 billion and R10.2 billion (Havenga *et al.*, 2016). However, this estimate is only indicative as there are insufficient data to determine whether the share of freight volume corresponds with the share of freight value. But what it does suggest is that inadequate road infrastructure investment potentially inflicts a sizeable output loss on producers and the economy.

3.4.4 Public capital durability

Agénor (2012), Devarajan *et al.* (1996), Rioja (2003), and the World Bank (1994) suggest that maintenance must be considered to fully understand the effects of road infrastructure on growth. Beyond South Africa, there are many examples where new road investment has been prioritised over road maintenance. At the same time as Brazil constructed 6 000 km of paved road between 1979 and 1984, 6 000 km and 2 000 km of road deteriorated from fair and good condition to poor condition, respectively (Harral, 1988). Following the upgrade of the 3 000 km north-to-south highway in Chile to paved standard in the 1960s, nearly half of this highway had collapsed by the 1970s due to inadequate maintenance (Rioja, 2003).

Insufficient road maintenance can shorten the occurrence of road rehabilitation from 15 to 5 years. A 3- to 5-year and 5- to 8-year delay in road maintenance typically reduce roads from a good condition to a poor and very poor condition, respectively (COTO, 2014). SANRAL (2016) and COTO (2014) demonstrate that in South Africa the cost to repair roads that have deteriorated to a poor and very poor condition are respectively 6 and 18 times higher than the cost to keep a road in good condition through preventative maintenance. Because there are no visible signs of road distress at the preventative maintenance phase it might not seem that this is the most efficient use of limited sources, but authorities must continue to prioritise road maintenance expenditure to avoid wasting resources on repeated road rehabilitation.

Because deteriorated roads have higher VOC and cost significantly more to rehabilitate than the cost of a well-designed preventative road maintenance regime, Devarajan *et al.* (1996) argue that an initially high public infrastructure stock, such as South Africa's road network, implies that at the margin an extra unit of maintenance expenditure may be more productive than investment in new roads. Rioja (2003) developed a dynamic general equilibrium model to evaluate the trade-offs of redistributions of funds between infrastructure construction and maintenance for 7 Latin American countries. Without further donor aid, reallocations from infrastructure construction to maintenance expenditure had positive effects on GDP.

Kalaitzidakis and Kalyvitis (2004) extended Rioja's (2003) study by using an infrastructure-led two sector endogenous growth model to theoretically investigate the macroeconomic impact of maintenance in the context of: the trade-off between infrastructure maintenance and new investment when both are financed domestically; and the implications of optimal maintenance policies for public capital formation on growth. Two conventional assumptions were made: the stock of capital affects output rather than its flow; and the depreciation and accumulation rate of public capital are determined by public spending on maintenance. Their model shows that the equilibrium private to public capital ratio falls as the economy suffers a waste of private capital due to misallocation towards new investment over maintenance. When a shortage of public capital is eliminated by increased allocation to maintenance, the subsequent accumulation of public infrastructure raises the shadow price of private capital and the economy reaches a higher steady-state growth rate. Moreover, this impact of maintenance expenditure on the steady-state growth rate increases total public spending through an elevated tax base.

3.4.5 Road accidents

Road accidents have a negative effect on economic growth. This effect is realised through, amongst other costs, the costs associated with casualty, treating injuries, ongoing care of persons with disabilities, vehicle repair, incident management, insurance administration, and emergency services. Based on the data shown in Table 3.2, the Road Traffic Management Corporation (2016a) estimated the human casualty, vehicle repair, and incident costs of the 11 144 fatal, 40 117 major (serious injury), 132 609 minor (slight injury), and 648 560 non-serious (vehicle damage only) road accidents in South Africa in 2015 at R143.0 billion, or 3.4% of GDP. This cost estimate is high compared to the average of 2.2% of GDP in low- and middle-income countries.

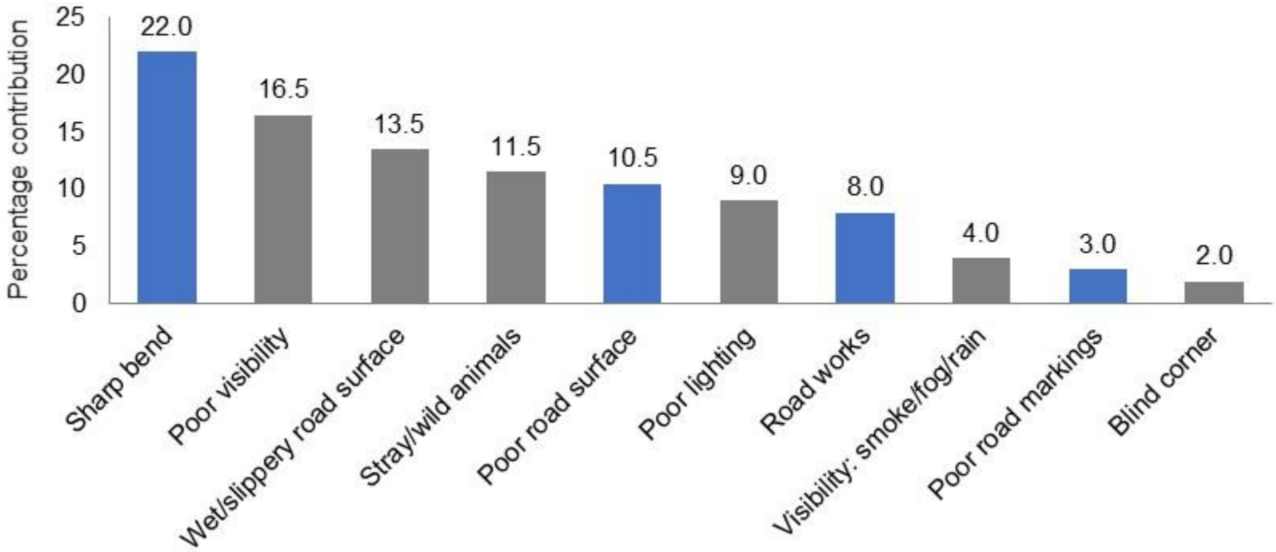
Table 3.2: Unit road traffic costs by cost category by category and element, 2016

Cost element	**Unit cost per road traffic crash**			
	Fatal	**Major**	**Minor**	**Damage only**
Lost productivity	R2 878 177	R217 253	R29 504	R2 094
Pain, suffering, and lost quality of life	R2 123 994	R287 173	R47 509	N/A
Medical treatment	R147 143	R110 656	R32 681	N/A
Funeral	R16 613	N/A	N/A	N/A
Work place re-occupation	R68 638	R2 949	N/A	N/A
Vehicle repair	R19 604	R20 171	R21 887	R26 822
Emergency response	R3 042	R2 765	N/A	N/A
Legal	R101 623	R101 623	N/A	N/A
Vehicle related	R3 107	R3 197	R3 469	R4 251
RTC management	R10 176	R5 101	R2 030	R2 030
Infrastructure damage	R1 596	R1 637	R2 023	R2 508
Delay congestion and emissions	R61 547	R13 140	R13 140	R10 829
Total unit cost	**R5 435 261**	**R765 664**	**R152 244**	**R48 533**

Source: Road Traffic Management Corporation, 2016a.

The Road Traffic Management Corporation (2016b) attributes 12.7%, or 1 348, of the 10 613 reported fatal road accidents in South Africa in 2015 to road and environmental factors. Figure 3.6 details the percentage contribution of the specific road and environmental factors to this 12.7%. Approximately 43.5% of these 1 348 fatal road accidents were attributed to road condition and road design factors, which equates to a cost of R3.2 billion. To the extent that road infrastructure conditions and designs also contribute to non-fatal road accidents in South Africa, road infrastructure investment that lowered these accident rates would free an additional R618 031, R109 694, and R2 094 per major, minor, and non-serious accident for alternative productive uses. Further gains in output would be realised through the stock and productivity of labour.

Figure 3.6: Percentage contribution of road and environmental factors to related fatal accidents, 2015



Source: Road Traffic Management Corporation, 2016b.

Table 3.3 details the accident rates and costs associated with different road types for South Africa. The data indicate the significant effect road infrastructure investment can have on road accident costs. For example, based on the fact that unpaved roads are associated with the highest accident rates and hence accident costs, if authorities upgraded unpaved gravel roads to paved single carriageways with an unpaved shoulder then road accident costs may fall by R69.6 billion per 100 million vehicle-km travelled on the upgraded roads.

Table 3.3: Accident rates and total accident cost per road class, 2016

Road description	Accident rates per 100 million vehicle-km			Accident costs per 100 million vehicle-km
	Fatal	Injury	Damage	
Unpaved Dirt Road	14	142	988	R188 591 089
Unpaved Gravel Road (Engineered)	12	123	857	R163 623 374
Single Carriage Unpaved Shoulder (Sh)	7	71	493	R94 053 140

Single Carriage Paved Sh < 1 m	7	68	471	R89 932 255
Single Carriage Paved Sh < 2 m	6	61	424	R80 866 308
Single Carriage Paved Sh < 3 m	6	58	406	R77 569 600
Single Carriage Unpaved Sh with IC	4	43	302	R57 692 390
Single Carriage Paved Sh < 1 m with IC	4	40	281	R53 571 505
Single Carriage Paved Sh < 2 m with IC	3	33	233	R44 505 558
Single Carriage Paved Sh < 3 m with IC	3	31	216	R41 208 850
Four Lane Road Unpaved Sh	7	66	463	R88 356 622
Four Lane Road Paved Sh	6	63	438	R83 629 725
Four Lane Road Unpaved Sh with IC	4	39	272	R51 995 872
Four Lane Road Paved Sh with IC	3	36	248	R47 268 975
Dual Carriage Unpaved Sh	5	51	358	R68 358 210
Dual Carriage Paved Sh	5	49	343	R65 449 350
Dual Carriage Unpaved Sh with IC	2	24	168	R31 997 460
Dual Carriage Paved Sh with IC	2	22	152	R29 088 600

Source: SANRAL, 2018.

3.4.6 Adjustment costs

Road infrastructure investment could reduce the incidence of adjustment costs associated with increases in private capital formation (Agénor and Moreno-Dodson, 2006). Adjustment costs represent frictions that inhibit firms from fully adjusting their capital stock to a change in market conditions, such as an increase in demand or productivity. For example, if a firm in a remote location wanted to construct a new factory in response to an increase in demand, adequate road infrastructure would reduce the cost to construct the new factory by, amongst other effects, lowering the cost to transport goods and heavy equipment to the construction site. According to Nordengen's (2004) study, adjustment costs in South Africa that are reliant on heavy vehicles to transport goods to site are inflated by 12.8% due to inadequate road infrastructure conditions. Road infrastructure investment is thus able, via lower adjustment costs, to raise expected rates of return and thereby stimulate private capital formation.

In addition, Agénor and Moreno-Dodson (2006) demonstrate that reduced adjustment costs from road infrastructure investment may facilitate the reallocation of capital from one sector to another in response to changes in relative prices. For example, road infrastructure that facilitates transport from farms to export points, such as a port, may allow farmers to more easily shift capital from the non-tradeable sector (cash crops in rural areas) to the traded sector (export crops). Lower adjustment costs from enhanced road infrastructure provision may therefore improve the ability of private firms to respond to price signals, which may be accompanied by efficiency gains, increased export production, and long-term growth effects.

Public investment in road infrastructure also enhances the reliability of road services, and thereby reduces or removes the need for road users to invest in substitutes to hedge against service interruptions (Straub, 2008). But when alternative transport modes are not available road users are often forced to undertake road maintenance in their private capacity. This is becoming a prevalent issue in South Africa, with legal proceedings from the High Court of South Africa (2017) citing multiple instances where commercial farmers were forced to incur significant costs to maintain roads that had been neglected by the Eastern Cape Department of Roads and Public Works for more than a decade. In a 2017 ruling the High Court ordered that the Department must reimburse farmers who carry out maintenance themselves subject to conditions including giving the department 30-day notice of the repairs and obtaining at least two independent quotes. This ruling, which is likely to set a precedent, affords isolated communities the opportunity to maintain access routes provided they have enough capital to initially fund the roadworks. While this arrangement is seemingly necessary until all road departments fulfil their duties, it is inefficient as the road departments should be in a better position to determine the required roadworks and realise economies of scale. Public road infrastructure investment that addresses this issue will realise budget savings, equal to the difference between what private users and the state would pay for road maintenance, and free private resources for investment in productive alternatives.

3.4.7 Inventory costs

Road infrastructure investment contributes to economic efficiency by reducing the need for firms to hold higher inventories. Inventory levels, which Guasch (2004) refers to as quasi-dead capital, have a significant effect on unit costs and country competitiveness through two primary channels: inventories have a significant financial cost because of the relatively high cost of capital in a developing country such as South Africa; and inventories have several associated costs such as taxes, insurance, storage, and obsolescence and spoilage.

Datta (2012) reviewed India's Golden Quadrilateral Program, which improved the highways connecting India's four largest cities, and found that affected firms reduced their average stock of input inventories by 6 to 12 days' worth of production. Li (2010) reviewed road investments in 36 major Chinese cities between 1998 and 2007 and found that raw materials inventories fell by 25.0% and that one dollar in road spending resulted in 1 to 2 cents of inventory decline, which is in line with the results reported by Henckel and McKibbin (2010) for the United States. Guasch and Kogan (2003) used an inventory survey of 51 countries to estimate that a one-standard-deviation worsening of infrastructure raised raw materials inventories by 11.0% to 37.0%. Guasch (2004) also argued that poor infrastructure quality and reliability in Latin America forced the affected firms to hold inventory levels one to two factors higher than those observed in industrial countries.

The inventory carrying and warehousing costs in South Africa were respectively reported at R65.0 billion and R62.0 billion in 2014, which cumulatively amount to 30.0% of total logistics costs (Havenga *et al*., 2016). These elements tie up a significant volume of firms' capital, raise unit costs, and lower productivity. Road infrastructure investment can therefore lower the domestic price of goods, raise the international competitiveness of local products, and promote private investment to the extent that it streamlines inventory levels in South Africa.

3.4.8 <u>Human capital formation</u>

Access to education and healthcare facilities are determinants of human capital formation. Individual productivity depends on skills and health status, with more skilled and healthier workers tending to be more productive, although there are diminishing marginal returns to both factors (Agénor, 2012). Health and education are also interlinked in their contribution to growth. Better health is an essential prerequisite for effective learning, enables individuals to remain in education for longer, and reduces the rate of depreciation of these skills (Agénor and Moreno-Dodson, 2006; Bleakley, 2010; Hazan and Zobai, 2006). While individuals with a higher level of education tend to be more aware of health risks and likely to address their health needs (Agénor, 2012).

There is wide literature on the education benefits of road infrastructure investment, typically through enrolment, attendance, and graduation rates. Agénor (2012) links the construction of a better and safer rural road network in the Philippines with a 10.0% increase in school enrolment and a 55.0% reduction in school dropout rates. Moreover, improved road access to schools led to the following outcomes: a 40.0% increase in the enrolment rate for girls in primary school in Morocco (Levy, 2004; Khandker *et al.*, 1994); a 31.0% and 42.0% increase in the respective school enrolment rate of boys and girls aged 6 to 16 in Bhutan (Levy, 2004); an 11.0% increase in the literacy rate in Indian Villages (Lebo and Schelling, 2001); and lower rates of teacher absenteeism (World Bank, 2008). However, Bell and Dillen (2012) caution that the accumulation of human capital from better road access to schooling may be dampened to the extent that classrooms become over-crowded.

There is a similarly wide literature on the health benefits of road infrastructure investment. Bloom *et al*. (2018) used a production function based on data from 116 countries from 1960 to 2010 to estimate that a 10.0% increase in adult survival rates raises labour productivity by about 9.1%. Wagstaff and Claeson (2004) found, using cross-section regressions, that the provision of road infrastructure had a significant effect on a number of health indicators including infant and female mortality rates. In addition, improved road access to healthcare facilities led to the following outcomes: an expansion of the rural road network in Morocco in the mid-1990s led to a significant increase in visits to primary healthcare facilities and clinics (Levy, 2004); mortality rates in the Philippines fall by 2.0% when travel time to a health facility is reduced by 10.0% (Booth *et al.*, 2000); and lower maternal mortality rates and improved labour productivity in Malaysia and Sri Lanka (World Bank, 2005a). Kinugasa and Mason (2007), Blackburn and Cipriani (2002), and Zhang and Zhang (2005) also show that higher survival rates induce higher savings to finance consumption in old age.

This channel between road infrastructure investment and growth is particularly relevant in South Africa given the poor access that some rural communities have to basic services due to the apartheid policy of separate development and the subsequent maladministration of the road sector (National Department of Transport, 2007). The Rural Transport Strategy for South Africa (Department of Transport, 2007) argues that limited road access to schools resulted in 3 million school children walking for over an hour to education centres. The travel strain associated with this separation has negative effects on enrolment ages and dropout rates, with half of every cohort that enters South Africa's school system unable to complete the 12-year schooling period (National Planning Commission, 2012). Econometric analysis of individual workers' wages in South Africa suggests that an additional year of education is associated with a 6.5% to 7.0% increase in wages, which reflects the expected increase in labour productivity (Clarke *et* al., 2007). The NDP also called for consideration of the road network's impact on health care outcomes (National Planning Commission, 2012). It is therefore possible that road infrastructure investment can improve the skills profile in South Africa and thereby lower the number of work seekers unable to enter the labour market, which are the third and fourth features of the low-growth middle-income trap.

The spatial separation of South African households from the nearest public primary school, secondary school, and healthcare facility are respectively shown in Figures 3.7, 3.8, and 3.9. The maps were generated from enumeration area data from the 2011 Census (Statistics South Africa, 2011), the 2016Q2 primary, secondary, and special school database (National Department of Basic Education, 2018); and the 2017 hospital registry (National Department of Health, 2017).

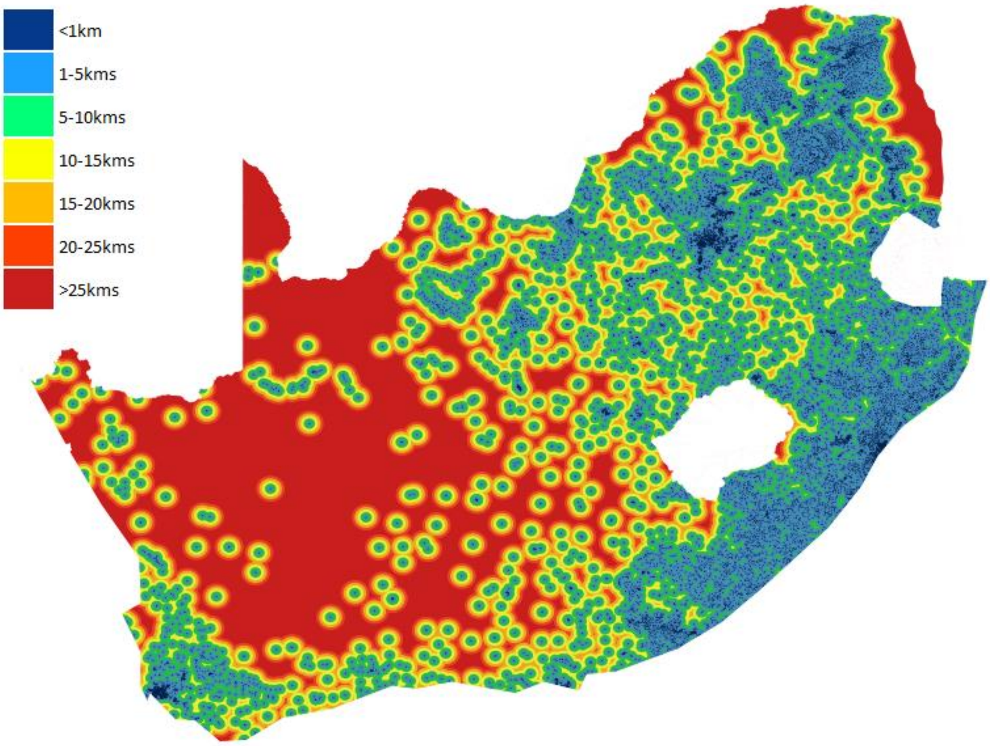
Table 3.4 and Figure 3.7 indicate that isolated rural communities across South Africa face significant spatial separations from the nearest primary school. The most isolated students are in the Northern Cape Province and must potentially travel as far as 101.1 km to attend a primary school. This signifies a significant transport burden on these students, especially given that most are between 6 and 13 years old. A similar, albeit lower transport strain is imposed on isolated primary school students in all of the other provinces except Gauteng.

Table 3.4: Access distance from Enumeration Area centre-point to the nearest primary school

Province	Mean distance	Max distance	Max (99 percentile)	Max (95 per centile)
Eastern Cape	1.4 km	49.4 km	9.5 km	3.1 km
Free State	1.7 km	32.5 km	16.1 km	7.5 km
Gauteng	0.9 km	14.0 km	4.9 km	2.3 km
KwaZulu-Natal	1.3 km	16.3 km	5.5 km	3.4 km
Limpopo	1.6 km	50.3 km	15.2 km	5.6 km
Mpumalanga	1.5 km	61.2 km	10.6 km	5.1 km
Northern Cape	8.1 km	101.1 km	63.3 km	41.2 km
North West	1.8 km	50.7 km	13.6 km	6.3 km
Western Cape	1.5 km	67.1 km	20.7 km	5.5 km

Source: Own calculations.

Figure 3.7: Distance to nearest primary school



Source: Own calculations.

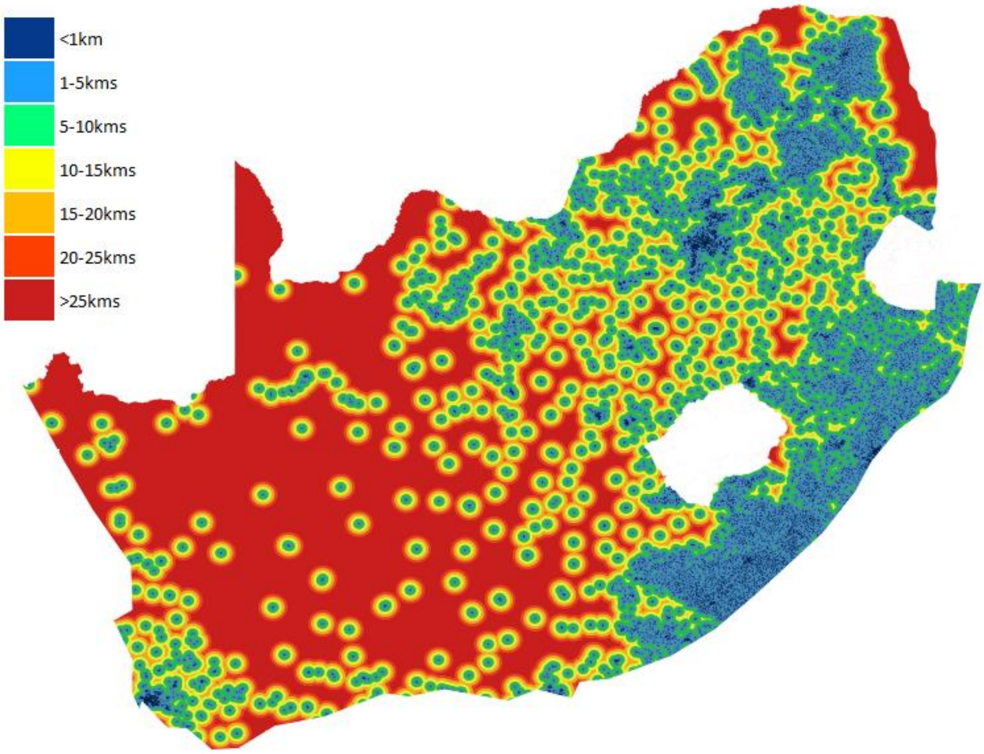
Table 3.5 and Figure 3.8 confirm that spatial separation between isolated households and secondary schools is a significant concern, even more so than for primary schools. The maximum distance students must travel to access the nearest secondary school is 122.1 km in the Northern Cape Province, with the best outcome being 19.2 km in Gauteng Province.

Table 3.5: Access distance from Enumeration Area centre-point to the nearest secondary school

Province	Mean distance	Max distance	Max (99 percentile)	Max (95 per centile)
Eastern Cape	1.9 km	65.6 km	15.1 km	4.3 km
Free State	2.6 km	37.9 km	23.4 km	13.4 km
Gauteng	1.2 km	19.2 km	7.0 km	2.9 km
KwaZulu-Natal	1.8 km	29.2 km	8.3 km	5.2 km
Limpopo	2.3 km	55.7 km	21.3 km	8.0 km
Mpumalanga	2.2 km	61.8 km	17.9 km	9.2 km
Northern Cape	11.5 km	122.1 km	73.3 km	52.5 km
North West	3.0 km	69.5 km	20.3 km	10.9 km
Western Cape	2.5 km	74.1 km	30.3 km	12.9 km

Source: Own calculations.

Figure 3.8: Distance to nearest secondary school



Source: Own calculations.

Table 3.6 and Figure 3.9 highlight the deficiencies in healthcare access. The most isolated communities are again concentrated in the sparsely populated Northern and Eastern Cape provinces. The most isolated communities in the Northern Cape are as far as 117.5 km from the nearest healthcare facility, which reflects a significant transport burden. 95.0% of citizens in all provinces, however, are within 9.2 km of the nearest healthcare facility.

Table 3.6: Access distance from Enumeration Area centre-point to the nearest healthcare facility

Province	Mean distance	Max distance	Max (99 percentile)	Max (95 per centile)
Eastern Cape	3.5 km	59.7 km	17.1 km	8.5 km
Free State	2.9 km	42.7 km	26.3 km	16.4 km
Gauteng	1.2 km	18.7 km	6.6 km	2.8 km
KwaZulu-Natal	2.9 km	29.0 km	14.4 km	8.6 km
Limpopo	3.8 km	74.6 km	28.6 km	11.0 km
Mpumalanga	2.8 km	62.1 km	19.9 km	10.9 km
Northern Cape	10.0 km	117.5 km	68.7 km	48.3 km
North West	3.2 km	41.5 km	22.8 km	12.4 km
Western Cape	3.3 km	68.8 km	28.3 km	8.4 km

Source: Own calculations.

Figure 3.9: Distance to nearest healthcare facility

Source: Own calculations.

3.4.9 Economies of scale and scope

Agglomeration economies arise when economic agents, namely firms and workers, benefit from their proximity to each other. Distance, or alternatively travel time, imposes a cost and time constraint on workers to reach their place of work and on the interaction between firms. Improved transport conditions bring firms and workers in neighbouring areas closer together, thereby improving the effective density of areas of production. As Venables (2007) shows using urban economic theory, raised accessibility to economic mass induces growth.

Firms derive several productive advantages from enhanced connectivity within the spatial economy: lower input prices from improved access to local suppliers; a larger labour pool from which firms can match their needs with available skills; increased labour productivity from shorter and less strenuous work commutes; easier access to information, innovations, and technology from physical clustering; and the rationalisation of multi-plant firms (Abelson, 2010; O'Flaherty, 2005; Jaffe *et al.*, 1993). For example, a study by Prud'homme and Lee (1999) of Paris and other French cities indicated that road and other transport infrastructure improvements widened the labour market and raised productivity by increasing travel speed. Without requiring any change in the location of employment road infrastructure investment can therefore improve productivity to the extent that it improves effective density, which is measured as the employment and number of firms in an area plus the employment and number of firms in adjacent areas weighted as a function of the cost of transport to the subject area (Abelson, 2010).

However, it is possible that a reduction in transport costs may reduce effective density if it encourages workers and firms to relocate further from central business districts. Abelson (2010) notes that improvements in transport infrastructure over the last 50 years, especially roads, have led to a decline in the proportion of employment in central business districts in many cities across the world as the congestion costs in these areas become prohibitively expensive. On this point, Straub (2008) lauds the ability of road infrastructure investment to facilitate the urban concentration process as well as to counteract agglomeration forces and promote regional development through inner city connections. This decentralising effect of road infrastructure investment would typically have a positive effect on productivity in South Africa given that the apartheid spatial planning, which is yet to be fully addressed, confines most of the labour force to the urban fringe.

The most robust evidence of the growth effects from agglomeration economies are from developed countries. Mare and Graham (2009) estimated agglomeration economies for New Zealand and found that the elasticity ranges from 0.032 for agriculture, forestry and fishing to 0.087 for finance and insurance. Graham *et al.* (2009) reported an average agglomeration elasticity of 0.04 in the United Kingdom, with elasticities varying from 0.02 for manufacturing and consumer services to 0.08 for business services.

International studies also confirm that road infrastructure investment can have a significant effect on the performance of special economic zones (SEZs), which are designated areas set aside for specific economic activities and targeted support through special arrangements and systems such as road infrastructure investment. The Dutch Directorate for Traffic and Infrastructure measured the impact of roads on regional economies in the Netherlands and found that successful zones with high job densities were systematically located near major roads (IRF Research Council, 2007). In addition, Mitsui (2004) reports the positive impact that the improvement of National Highway No.5 in Vietnam in the early 1990s had on the growth, employment, and investment rates in the associated major industrial zones.

The Road Access Guidelines acknowledge the importance of agglomeration effects in South Africa (Provincial Administration Western Cape, 2002). An obvious example are the 7 SEZs established by the Department of Trade and Industry to promote growth, employment, and exports of value-added commodities: Coega Industrial Development Zone (IDZ); Richards Bay IDZ; Saldanha Bay IDZ; Dube TradePort; Maluti-A-Phofung SEZ; OR Tambo SEZ; and Musina/Makhado SEZ. The IDZs are near ports and hence their logistics rely on an efficient land-to-marine transport network, whereas the SEZs are close to regional economic centres and rely on efficient road corridors and the road-to-air transport network. Hence, the NDP and NDoT (2006) stress the need for adequate road infrastructure investment to stimulate the intended agglomeration forces (National Planning Commission, 2012).

3.4.10 Agricultural output

Roland-Holst (2006) explains that agricultural margins are inversely related to the rural terms of trade, as shown in Equation 3.2. Where ρ is the rural terms of trade, P_R^{R} is the rural price of rural products, P_U^{R} is the rural price of urban products, P_D is the domestic market price, and M is the distribution cost. This explains that rural household producer prices must be debited for transport costs to the domestic market, and rural household purchaser prices must include transport costs from domestic markets. It is thus evident that lower transport costs improve the rural terms of trade.

$$\rho = \frac{P_R^{\mathrm{R}}}{P_U^{\mathrm{R}}} = \frac{P_D - M}{P_D + M} \qquad 3.2$$

Improvements in the rural terms of trade through road infrastructure investment provides farmers with cheaper access to external markets, which potentially raises output, household income, investment, and growth. This impact is particularly relevant in developing countries for small-scale and household farmers, who are often located in isolated rural areas. In fact, Dennis (1998) reports that small-scale farmers in Sub-Saharan Africa lost between 30.0% and 50.0% of the value of their crops from costs imposed by limited transport infrastructure and services. Dennis (1998) also highlights the importance of road infrastructure to farmers through reference to Indonesia, where trucks account for 0.5% of trips to market but 57.0% of goods moved. Heavy reliance on road transport is common across countries, especially if farmers are to access primary and secondary markets where there is often higher demand and higher prices than in local markets.

Jacoby (2000) explains that better road infrastructure means small-scale farmers are better able to form cooperatives and thereby achieve economies of scale when their produce is ready to be transported. As per the NDP requirements, road infrastructure investment is thus able to facilitate new intermediaries, such as cooperatives, to help small producers achieve economies of scale in processing and transporting (National Planning Commission, 2012).

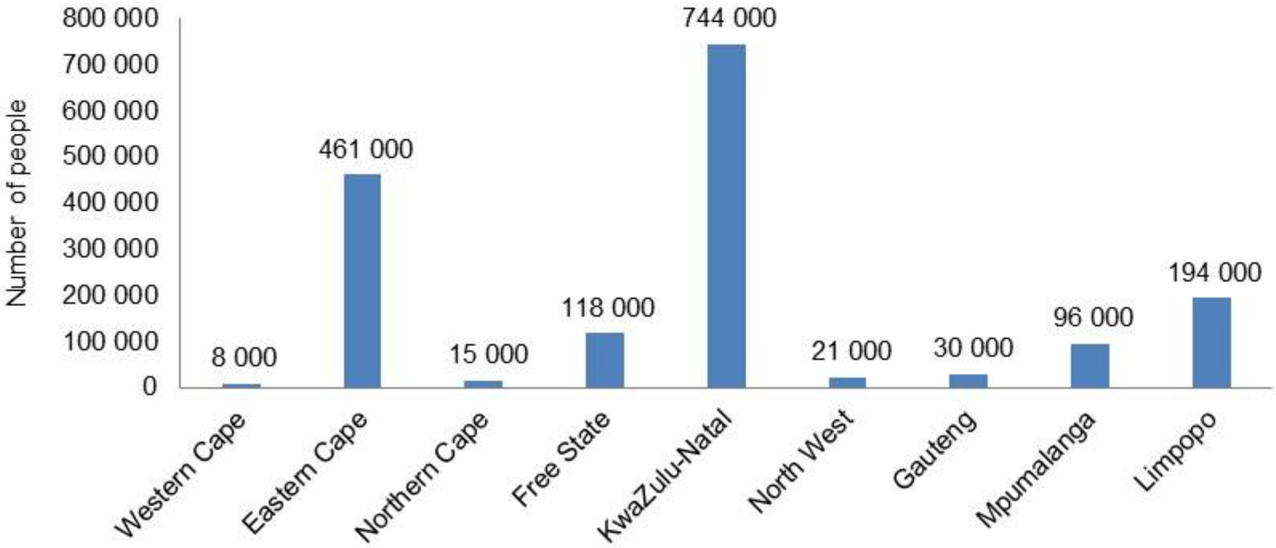
Better market access through road infrastructure investment allows farmers to more easily procure farming inputs such as fertilizers, seeds, and pesticides. Notable studies include: Kiprongo and Matsumoto (2014) who report a positive relationship between road access to large towns and organic fertilizer intensification in 15 districts in Kenya; Jacoby (2000) who found a negative relationship between the quantity of chemical fertilisers used per hectare by farmers in Nepal and the travel time to the nearest market; Binswanger *et al*. (1993) who show that road infrastructure investment generated a higher usage of fertilisers in 85 districts in 13 states in India; and Khandker *et al.* (2009) who found that road development reduced the price of fertilizer for farmers in Bangladesh. These studies additionally show that greater availability of farming inputs through lower transport costs can increase agricultural output, which adds to the volume of surplus produce marketed by small-scale farmers and allows some subsistence farmers to generate an income.

Many studies confirm that road infrastructure investment shifted farmers' production frontiers outwards, including: Binswanger *et al.* (1987) who reviewed annual observations from 1969 to 1978 for 58 countries and found a positive correlation between crop yield and roads paved and road density, with respective elasticity coefficients of 0.305 and 0.058; USAID (1978) who assessed 586 households in the Philippines that were affected by the construction of 6 rural roads and found that production volumes of 7 marketable crops increased by almost 40.0% and there had been a 59.0% increase in farmgate prices; Ahmed and Hossain (1990) who studied 129 villages in Bangladesh and found that villages with better road access had higher agricultural output and total income; Levy (1996) who found that development of rural roads in Morocco led to significant increases in agricultural output and extensions to farmers' crops portfolio; Escobal (2001) who compared two geographic areas in Peru, one connected to markets via motorised rural roads and the other connected to the same markets via non-motorised rural roads, and found that transaction costs associated with marketing crops was markedly lower in the areas connected by the motorised roads; Lebo and Schelling (2001) who found that road infrastructure investment had a notable effect on agricultural transport costs in India and Bangladesh; Fan *et al*. (2004) who link shortened distances to feeder roads in Uganda with higher agricultural labour productivity; and Minten and Stifel (2008) who confirm that rice, maize, and cassava yields in Madagascar are lower in isolated areas relative to non-isolated areas.

This body of international evidence supports the rural development strategy promoted by the NDP, which calls for investment in a transport network that supports regional and local food production systems and local rural economies (National Planning Commission, 2012). The expectation is that targeted road infrastructure investment should help raise agricultural output, support small farmers, protect producers and consumers from rising transport costs, bring the more than one-third of South Africa's population that live in former homelands into the mainstream economy, reduce national food security risks, and create 1 million additional work opportunities in micro and semi-subsistence farming.

In terms of these objectives, Figure 3.10 indicates the number and location of subsistence farmers in South Africa. Within this cohort are a subset of citizens whose expansion to small-scale farming is primarily constrained by road access. According to this information there were roughly 1.7 million citizens involved in subsistence farming activities in 2018Q2, which is significantly less that the 2.9 million households recorded in the 2011 Census (Statistics South Africa, 2011). Most of the subsistence farmers are in the former homeland provinces of the Eastern Cape and KwaZulu-Natal, which conforms with the NDP target to provide innovative market linkages for small-scale farmers in communal and land-reform areas that usher farm products to and through the value chain and to markets.

Figure 3.10: Involvement in subsistence farming by province, 2018Q2



Source: Statistics South Africa, 2018c.

This channel between road infrastructure investment and growth may become increasingly relevant given the possibility of revisions to land redistribution policy. President Ramaphosa announced as part of the economic stimulus and recovery plan the establishment of a 10-person panel to advise government on the implementation of a fair and equitable land reform process that redresses past injustices, increases agricultural output, promotes economic growth, and protects food security (The Presidency, 2018). The initial indications are that the focus will be on redistributing underutilised and unutilised land to local communities for productive use. Such policy would require commensurate road infrastructure investment to support these farmers, especially in previously unutilised areas.

Finally, road infrastructure investment that supports small-scale farmers could contribute to the NDP objective to increase national savings from 16.0% of GDP to 25.0% of GDP. Like South Africa, livestock remain a form of savings mechanisms for rural households in Peru. Escobal and Ponce (2002) show that road rehabilitation projects in rural Peru increased the value of affected households' livestock holdings by 65.0%, which was equivalent to 56.0% of their average annual per capita income. This is one means, albeit through an alternative mechanism to the conventional financial market, to address the low savings feature of the low-growth middle-income trap.

3.4.11 <u>Rural income and rural-urban migration</u>

Inadequate rural incomes, few job opportunities, and insufficient connective infrastructure in South Africa have forced people to relocate from isolated rural communities to settle in urban centres or along transport corridors (National Planning Commission, 2012). These factors have led to a high rate of rural-urban migration, with the urban population increasing from 57.0% in 2001 to 63.0% in 2011 due to the movement of 6.8 million citizens from rural to urban areas (Statistics South Africa, 2011). The United Nations (2010) estimates that South Africa's urban population will grow to 71.3% by 2030 and 80.0% by 2050.

In response to these migration patterns, the NDP calls for rural infrastructure investment to incentivise citizens to remain in rural areas and to ensure that those who stay in rural areas are not locked into poverty and their life chances improve (National Planning Commission, 2012). As part of this objective the aim is to grow the rural employment rate from 29.0% to 40.0%. Road infrastructure investment can assist with this objective as it often enables rural citizens to diversify from or to substitute agricultural self-employment income for other, more profitable income sources such as non-agricultural self-employment and waged activities.

Many studies demonstrate that road connectivity to markets provides rural households with greater opportunities to participate in more income earning activities and to increase existing wage incomes. Relevant examples include: Combes and Lafourcade (2005) who show that while road infrastructure made only a minor contribution to the decline in transport costs in France between 1978 and 1998, it was road policy that determined the distribution of the economic gains; Jacoby and Minten (2008) who used cross-sectional data from Madagascar to show that road infrastructure investment in isolated areas raised household income by nearly 50.0%, mostly through non-agricultural earnings; Gibson and Rozelle (2003) who found that in Papua New-Guinea the number of income-generating activities undertaken by households decreased by 2.6% for each extra hour to reach the closest road; Lanjouw *et al.* (2001) who show that road projects in Tanzania increased non-agricultural employment; Mu and van de Walle (2007) who show that road projects in Vietnam increased employment opportunities for unskilled labour by 11.0% and also reduced household reliance on the agricultural and forestry sectors; Smith *et al*. (2001) who link road rehabilitation projects in Uganda with more job opportunities in the service sector; Akee (2006) who reviewed a road construction project in the Republic of Palau that linked an isolated rural area to an urban centre and found that the new road increased rural citizens' wage sector employment while decreasing their self-employment in agriculture by 38.0% and decreased intra- and inter-region inequality; Corral and Reardon (2001) and de Janvry and Sadoulet (2001) who found a significant relationship between road indicators and non-agricultural rural employment in self-employment and waged activities in Nicaragua and Mexico, respectively; and Escobal and Ponce (2002) who found Peru's Rural Road Rehabilitation and Maintenance Program raised annual agricultural, non-agricultural, and self-employment incomes of the beneficiary population by 35.0% compared to the control households.

Without this increase in rural incomes and employment opportunities it is possible that road infrastructure investment may rather accelerate rural-urban migration rates by lowering the transport costs of moving. There are, however, many examples that demonstrate the ability of road infrastructure investment to slow rural-urban migration. Fafchamps and Shilpi (2009) show that better access to paved roads in Nepal reduced rural-urban migration, Gachassin (2013) estimates that upgrading trunk roads to asphalt in the Kagera region of Tanzania lowered the probability of rural-urban migration by 7.2%, Jacoby (2000) links the extension of the road network in Nepal with a tendency for poorer households to live farther away from towns and markets, and Akee (2006) found that a new road project in the Republic of Palau decreased the number of rural migrants by 20.0%.

The importance of slowing rural-urban to a manageable rate is highlighted by the high levels of traffic congestion and the incidence of infrastructure failure and backlogs in South Africa's metropoles and secondary cities. According to the 2018 Integrated Urban Development Framework the waste collection, sanitation, water, and electricity sectors already need an extra R16.0 billion per annum over the next 5 years to eradicate urban backlogs (Department of Cooperative Governance and Traditional Affairs, 2018). Additional growth in the urban population from rural-urban migration would exacerbate these backlogs. Road infrastructure investment is a vital means to strengthen the link between rural and urban areas and thereby ease rural-urban migration to a rate commensurate with urban infrastructure development.

3.4.12 Land values

The benefits of road infrastructure investment are sometimes capitalised into asset values such as the value of the surrounding land. Over-and-above other land-related benefits from road infrastructure investment such as increased potential rental income from properties, higher land values potentially increase household and commercial access to capital through enhanced credit facilities that in turn lifts private consumption expenditure and investment.

In urban areas road infrastructure investment is expected to have a positive effect on access conditions and hence land values. For example, Gonzalez-Navarro and Quintana-Domeque (2012) show that within two years of first-time street asphalting in Acayucan, Mexico, the households whose streets were paved leveraged their higher housing wealth, through collateralised credit use, to increase consumption and investment expenditure. But major road infrastructure investments such as a highway generally have a combination of positive and negative effects. As Bowes and Ihlanfeldt (2001) explain, there is typically a buffer zone within the immediate vicinity of a major transport project from which the impact on land values shifts from a negative to a diminishing positive effect as the access benefits decrease. The negative effect results from the noise and air pollution from a major road investment. Smith and Huang (1995) conducted a meta-analysis of 37 published studies which verified the negative effect of air pollution on property values. Further evidence is provided by Kim *et al*. (2003), Ridker and Henning (1967), and Carey (2001), who respectively find a strong negative relationship between property values and transport related air pollution in Seoul, Illinois, and the cities of Mesa and Gilbert in Arizona.

In isolated rural areas the relationship between road infrastructure investment and land values is often positive. As indicated by Jacoby (2000), if farmland behaves like a typical asset then its price would equal the net present value of the benefits its cultivation generates. The relation between farmland value and the travel time to agricultural markets is thus an indicator of the capital gains generated by the improvement of road infrastructure. Notable examples of this relationship include Jacoby (2000) who analysed 13 651 plots in Nepal and found that a 10.0% increase in travel time to the nearest market reduced the value of land by 2.2%, and Binswanger *et al.* (1993) who link road infrastructure investment in 85 districts across 13 states in India with higher credit supply through increased land values.

Another benefit of increased land values from road infrastructure investment are the revenue windfalls, referred to as land value capture. Land value capture refers to the appropriation of the value generated by public infrastructure investment, through public revenues, for local reinvestment to produce more public goods and further potential private benefit. As Halvey *et al.* (2017) explain, there are a variety of charges beyond rates, taxes, and transfer duties that South African municipalities can levy on private landowners to recoup a portion of the increased land values generated by road infrastructure investment. With 96.4 million and 5.3 million hectares of agricultural and urban land in South Africa, respectively, there is large scope for road infrastructure investment to generate significant public revenue windfalls for municipalities that can then be directed to productive uses (World Bank, 2018b).

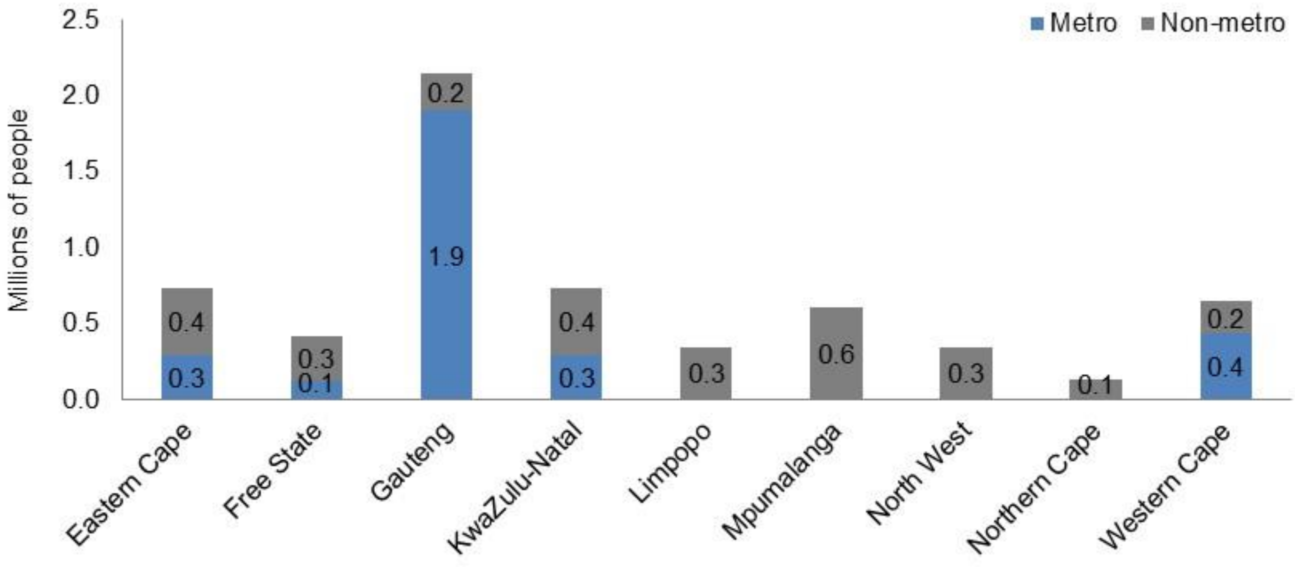
3.4.13 Utilisation and skills of underemployed and unemployed workers

Public infrastructure spending has long been a popular means to directly stimulate short- or medium-term transitory employment, with examples like the Worker Protection Act in the United States and the large countercyclical and recurrent fiscal commitment to public works in Japan. The primary goal of these Keynesian stimulus programmes is to generate work opportunities to involve unemployed and underemployed citizens, especially in rural areas where there are few alternative formal work opportunities, in productive activities. This in turn generates incomes, increases consumption expenditure in the local economies, and stimulates growth and private investment. Stakeholders such as the International Labour Organisation (2013) and Department of Public Works (2012) additionally promote labour-based road construction and maintenance as a means to reduce project costs and lower the inefficient use of machinery and foreign inputs.

Road infrastructure investments that utilise underemployed and unemployed unskilled rural labour are especially appealing in the South African context. Seekings and Nattrass (2005) explain that historically South Africa was characterised by an extensive system of agriculture that was primarily constrained only by the availability of labour that could be mobilised to work on it. Because these conditions meant that urban manufacturing firms had to pay higher wages, the apartheid government undertook to coerce the rural peasantry into wage labour through restricted access to land. This entailed resettling African peasantry from productive land to overcrowded bantustans where the productivity of land steadily declined. To avoid a situation of food price inflation, the African peasantry were replaced by an efficient, capital-intensive commercial agriculture sector operated by white farmers. One of the lasting effects of this forced proletarianisation is that the subsistence and peasant farming sectors are too weak to provide any alternative means for underemployed and unemployed rural workers to earn a living. As such, the opportunity cost of these workers' time is very low, if not close to zero in many parts of the country.

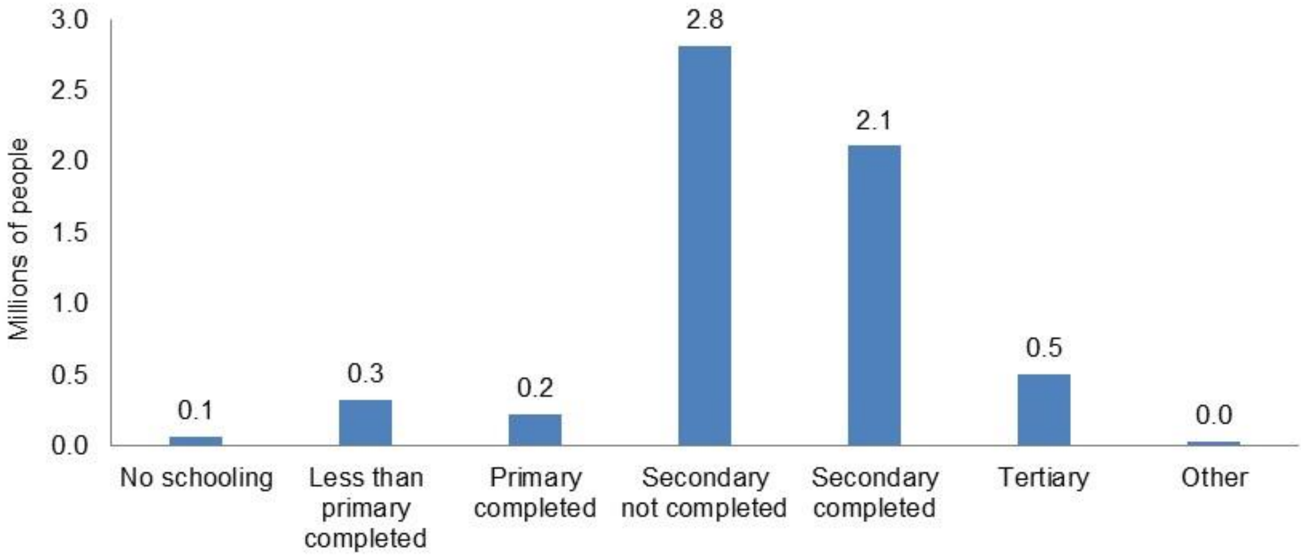
Figure 3.11 indicates the location of unemployed workers in South Africa in 2018Q2. The 6.1 million unemployed workers were approximately evenly split between the metro and non-metro areas, with 3.0 million unemployed workers located outside the metropoles. Figure 3.12 shows that in 2018Q2 the South African labour force comprised 500 000 skilled workers and 5.5 million semi and unskilled workers. Hence, there is a large pool of underutilised semi and unskilled rural labour that authorities can utilise for road works through programmes like the Expanded Public Works Programme (EPWP).

Figure 3.11: Location of unemployed workers, 2018Q2



Source: Statistics South Africa, 2018c.

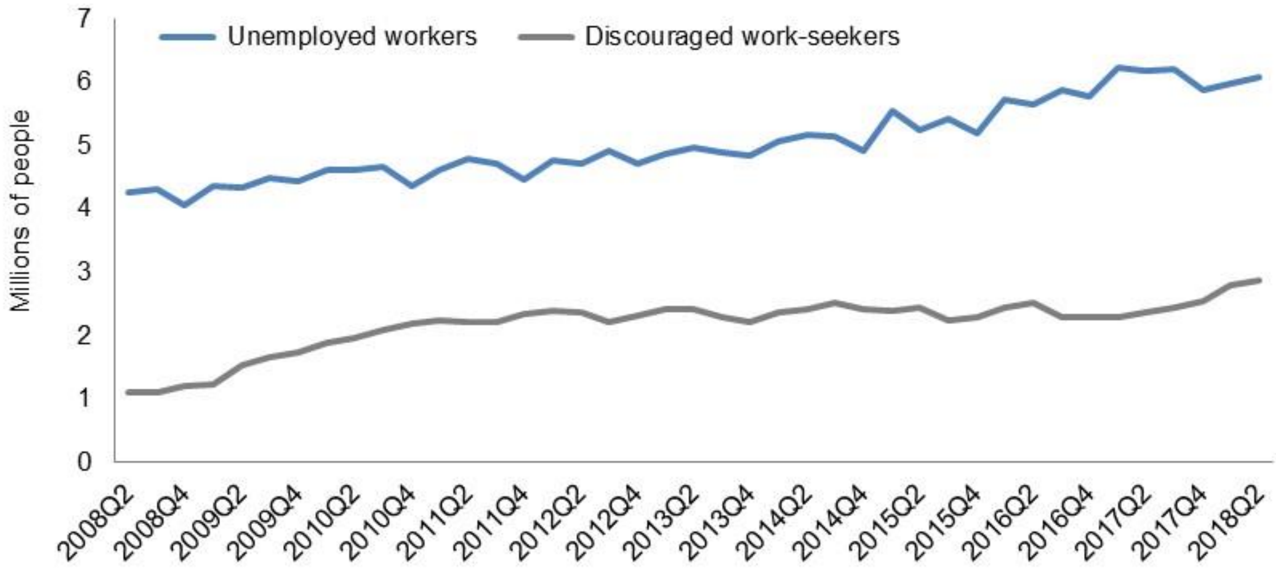
Figure 3.12: Highest level of education of the unemployed, 2018Q2



Source: Statistics South Africa, 2018c.

The NDP acknowledges that South Africa's unemployment problem is too big for market-based solutions to solve in the next 10 to 20 years (National Planning Commission, 2012). Figure 3.13 shows the growth in unemployed and discouraged work-seekers, which reached 6.1 million and 2.9 million people in 2018Q2, respectively. The NDP aims to expand public employment programmes to 2 million participants by 2020, with the size of this programme appropriately scaled down as the number of formal- and informal-sector jobs increase.

Figure 3.13: Unemployed workers and discouraged work-seekers, 2008-2018



Source: Statistics South Africa, 2018c.

The NDOT (2018a) has listed the following policy statements as part of the 2018 Draft Roads Policy for South Africa: labour-intensive road construction and maintenance methods must be used wherever cost, time and quality are not compromised; employment-creation efforts within the roads sector must focus on the creation of multifaceted employment opportunities, including casual, temporary and permanent employment for semi and unskilled individuals; road projects must be used to provide short- to long-term employment to local unemployed people and to provide some form of training and skills development to equip people for the labour market; and projects on secondary and rural roads must support efforts to provide employment opportunities to rural communities, especially in marginalised areas.

Howe (2001) traces the successful reverse substitution of labour for equipment on road projects by road authorities in Sub-Saharan Africa from the 1970s. Based on research by the International Bank for Reconstruction and Development (1986), which found that it was technically feasible to substitute labour for equipment for all but 10.0% to 20.0% of total road construction costs, developing countries began to interrogate the application of first-world capital-intensive roadwork methods where only 10.0% of project costs were labour related. Examples of labour-intensive road programmes include: the 1975 Kenyan Rural Access Roads Programme which used labour-intensive methods to construct 8 000 km of road and generated 120 000 years of employment and increased the proportion of road expenditure that remained inside Kenya from 28.0% to 69.0% (International Bank for Reconstruction and Development, 1986); the 1974 District Roads Improvement and Maintenance Programme in Malawi which generated 6 800 unskilled labour opportunities to construct and maintain 5 500 km of roads and raised the proportion of labour related project costs to 38.0% (Hagen and Relf, 1988); and the Malawian Social Action Fund which ran from 1995 to 2003 and generated 13 million person-days of employment to construct and maintain approximately 9 000 km of roads with 38.0% of the budget channelled towards labour (Ngoma, 2003).

The infrastructure sector provides the highest levels of employment generation in the EPWP, and within that roads provide the highest employment creation potential (Department of Public Works, 2012). But the labour intensity of roadworks in South Africa in 2010/11 was at 13.0% and 9.0% for the provincial and municipal road authorities, respectively, which is only slightly above conventional capital-based methods and significantly below the levels (38.0%) achieved by other countries with labour-intensive roadworks programmes such as Kenya and Malawi (Department of Public Works, 2012). To correct for this relatively low proportion of labour in road project costs the Department of Public Works (2012) has called for the wider application of programmes such as Zibambele and Sakha Sizwe, which are based on the Kenyan model and appoint local households to conduct road maintenance using labour-intensive methods, and S'hamba Sonke. Hence, there is significant scope to generate semi and unskilled employment opportunities through effective trade-off of capital for labour in road infrastructure investment and to utilise the on-the-job skills training on road projects to raise potential growth through enhanced labour productivity.

3.4.14 Regional integration and trade

Road infrastructure investment can improve a country's trade potential in a relatively non-discriminatory manner by, amongst other effects, removing the geographic barriers to trade, decreasing the cost to undertake trade, extending producers' access to foreign resources and markets, broadening consumers' access to goods, reducing the price of imported capital goods, and supporting technology transfer (Fujimura, 2004). Road infrastructure, along with other transportation infrastructure, is therefore a key component of a state's export system. Turner and Johnson (2017) refer to the logic of the competitive state to argue that national infrastructure systems, in which the road network is central, are a platform for the strategic global and regional positioning of the state.

As Roland-Holst (2006) explains through Equation 3.3, road infrastructure investment that lowers transport costs improves the international terms of trade. Where M is the distribution cost, PWE is the international price of an export good, PWM is the international price of an import good, and P_D is the domestic market price. The first term, $PWE - M$, denotes the domestic producer price of exports (PE) where transport costs must be debited against the exporter's net revenue price. The second term, $PWM + M$, denotes the domestic purchaser price of imports (PM) where transport costs must be added to the purchaser price of imported goods. Roland-Holst (2006) shows that lower transport costs induce an increase in terms of trade PE/PM. The double virtue of lower transport costs and increasing producer prices while reducing purchaser prices raises the incentive for trade.

$$M \downarrow = \frac{PWE - M}{P_D} \uparrow \ and \ \frac{PWM + M}{P_D} \downarrow \qquad 3.3$$

Notable examples of road infrastructure investment projects that were intended to generate growth through regional integration include: the 2013 Belt and Road Initiative, which among other developments improved relevant road infrastructure along 6 strategic corridors (China-Mongolia-Russia Economic Corridor; New Eurasian Land Bridge; China–Central Asia–West Asia Economic Corridor; China–Indochina Peninsula Economic Corridor; China-Pakistan Economic Corridor; and Bangladesh-China-India-Myanmar Economic Corridor) with the preliminarily data indicating a 38.0% reduction in average trading times and 14.4% to 21.5% increase in average trade volumes (Baniya *et al.,* 2018); improvement in the quality of the Dakar-Lagos Highway which was forecast to increase annual trade between the associated Economic Community of West Africa State countries by 5.3% (Akpan, 2013); and the 23 transnational roads included in the Association of Southeast Nations Highway Network that supported the export-led growth strategy of many South East Asian countries (Fau, 2017).

In addition to effective road access to ports and logistics hubs, as part of the exports-led growth strategy the NDP promotes transport infrastructure investment that connects South Africa with the various South African Development Community (SADC) markets (National Planning Commission, 2012). Although each of the SADC markets is relatively small, they are currently growing and combine to form a substantial consumer base. The NDP prioritises transport infrastructure programmes that support regional supply chain integration - such as the Maputo Corridor, the Trans-Kalahari Corridor, and the North–South Corridor - in the expectation that intra-regional trade in Southern Africa will grow from 7.0% of South Africa’s trade in 2010 to 25.0% by 2030.

3.4.15 Road infrastructure investment policy as a form of industrial policy

Road infrastructure investment policy is claimed to be a form of industrial policy. Because trade corridors and urban roads often facilitate the movement of large volumes of diverse goods, road infrastructure investment allows policy-makers to improve the general business environment and then to rely on market dynamics to select the winning sectors (Fedderke and Garlick, 2008). Glykou and Pitelis (2011), for example, argue that in the context of global markets the most effective industrial strategy is to generate productive efficiency by lowering the production and transaction costs faced by firms through improved logistics systems.

The NDP highlights the tension in industrial policy between the government picking and supporting beneficiaries and the alternative open-architecture approach where government support is informed by market-based mechanisms (National Planning Commission, 2012). Because South Africa demonstrates competitive capabilities in a range of minerals and fast-growing goods and service activities, the country's industrial policy has increasingly focused on a diversified industrial and services base. But South Africa's industrial policy remains a combination of both approaches, with the NDP, New Growth Path, and the Industrial Policy Action Plan still pre-selecting specific sectors for government support. Road infrastructure investment is therefore a means to hedge against uncertain pre-selections by providing non-discriminatory support to any firms, over-and-above the potential group of intended primary users, that make use of the maintained road network. This generalised approach to industrial policy poses fewer risks to narrowing the potential investor base in the economy.

3.5 CONCLUSION

Road infrastructure investment contributes to growth through a myriad of potential direct and indirect effects. Many of these effects are more pronounced due to the prevalence of inter-regional value chains and the implementation on an exports-led growth strategy for South Africa. Hirschman's (1960) theory of unbalanced growth suggests growth is communicated in an uneven fashion from one sector of the economy to another, with support for master industries in the form of road infrastructure investment expected to generate upstream and downstream benefits in connected sectors. Perkins et al. (2005) argue that for South Africa causality runs from road infrastructure investment to growth. But whilst the indication is that many of the effects of road infrastructure investment on growth are highly relevant in the South African context, the degree to which road infrastructure investment will affect growth, and whether this contribution is even positive, depends on the efficiency of the investment.

While there is a significant body of international and local studies that point to the economic benefits of road infrastructure investment, there are also examples that warn policymakers of the risks associated with inefficient expenditure. Amongst other effects, insufficient or poorly targeted road infrastructure investment could increase transport costs, limit citizens' access to basic services and places of work, and thereby subdue levels of private investment and growth. On the other hand, overcapitalisation in road infrastructure risks crowding out private investment. The likelihood of these risks is accentuated by the high number of road authorities in South Africa who independently plan their investment schedules and the fact that policymakers often have a perverse incentive to prioritise road construction over road maintenance as the former, regardless of its economic merit, is more visible and therefore politically attractive.

Ideal road infrastructure investment policy would therefore promote the objective that, within the constitutional constraints, the limited budget for the roads sector is allocated such that the combined direct and indirect effects of road infrastructure investment on growth are maximised. Without informed policy guidance it is uncertain whether road infrastructure investment will deliver on its significant potential to help address the structural challenges that have led South Africa into the low-growth middle-income trap and to fully contribute to the NDP vision of an inclusive, export-orientated, and high growth economy.

4 THE CONDITIONS AFFECTING ROAD INVESTMENT

Having respectively established in Chapters 2 and 3 the importance of road infrastructure and road infrastructure investment policy to the South African economy, it is necessary to understand the conditions under which road investment policy is set and implemented in South Africa. This chapter specifically explores the need for road authorities to prioritise their road infrastructure investment schedules given the extent of the road maintenance backlogs. Prioritising road investment is a complex task that carries a risk of inefficient expenditure outcomes. This task is further complicated by the low levels of asset management maturity and skills deficit within the sub-national road departments where road maintenance backlogs are highest. The appreciation that is gained for this situation through this chapter motivates and guides the development in subsequent chapters of methods to minimise the disruptive effect of road investment prioritisation on the network's ability to deliver on its mandate to address citizens' basic rights, develop human capital, and grow the economy.

Section 4.1 explores the road asset management maturity and skills profile of South Africa's public sector roads departments. The situation is analysed for SANRAL and the sub-national road authorities through their respective asset management systems and employment and skills profiles. While SANRAL is suitably staffed, many of the provincial and municipal road authorities have insufficient numbers of skilled and experienced staff to efficiently manage long-term investment planning, project selection, and maintenance scheduling. Although there is an increasing number of qualified junior staff, there are still limited numbers of experienced staff to provide the necessary training and skills transfer to this junior cohort. This constraint is therefore a structural impediment to road infrastructure investment that must be controlled for by the road authorities.

Section 4.2 estimates the road maintenance backlogs in 2017 for the national, provincial, municipal, and unproclaimed road networks. The analysis confirms that all road authorities are affected by funding shortfalls, but most notably the sub-national road authorities. Section 4.2.1 introduces the estimation methodology and sets the parameters for the main factors that drive the road maintenance backlog. This information is then applied in Section 4.2.2 to estimate plausible ranges for the functional and technical needs budgets, which estimate the cost to lower the volume of paved and gravel roads in poor and very poor condition to

10.0% and 0.0% of the network, respectively. The total functional and technical needs backlogs were respectively estimated at R305.0 billion and R416.6 billion in 2017. These modelled road maintenance backlogs are analysed in the context of the road maintenance budgets and 2018/19 Medium-term Expenditure Framework (MTEF) to indicate the extent to which road investment is influenced by fiscal pressure.

4.1 ROAD ASSET MANAGEMENT CAPABILITY

Asset management incorporates a range of principles, concepts, and processes to translate organisation objectives into decisions and actions on road assets. TMH 22 explains that this complex process is dependent on, amongst other factors, a capable pool of skilled staff as a core enabler of effective road asset management (Committee of Transport Officials, 2013). Insufficient numbers of experienced and skilled staff in a road authority can, and often does, hinder the efficiency of long-term investment plans through misinformed works schedules.

TMH 22 lists the following four levels of asset management maturity within an organisation: *Initiative*, where staff are aware of asset management benefits and the need for consistent and good quality data, but only individuals take the initiative to explore, apply, and improve road asset management systems to see how they can be adapted to meet the developing needs of the authority; *Proficient*, where road asset management is embedded within an authority and the necessary data is available to respond to most questions about road asset inventory, condition, value and the probable quantum of funding required to maintain the road network; *Advanced*, where the use of road asset management systems is routine for all staff and these systems are supported by the necessary data to influence the authority's programme and work methods and to guide maintenance standards, designs, procurement and specifications; and *Excellence*, where all road asset management policies, processes, and procedures are routinely improved to respond to increasingly challenging questions and to ensure a high level of value for money for funds invested in road assets (Committee of Transport Officials, 2013). Table 4.1 describes the levels of road asset management as laid out in TMH 22.

Table 4.1: Maturity levels of road asset management

	Initiative	Proficient	Advanced	Excellence
Policy	Expectations set in vision and mission statements.	Defined policy statements for service levels and minimum conditions.	Achievements reviewed and policy statements adjusted to reflect plans.	Policy statements reviewed and integrated into business processes.
Inventory	Detailed listing of all roads.	Integrated GIS and road and bridge inventory together with engineering details of each link.	Roads divided into components with different expected useful lives and construction details.	Inventory integrated with asset register, acquisition data, and performance information.
Valuation	Valuations per km or square meter of each road type.	Valuations per square meter of road type adjusted for expected useful life.	Valuations adjusted for estimates of remaining useful life and unit costs.	Valuations adjusted for remaining useful life and unit costs based on current construction costs.
Condition and use	Visual evaluations of condition of each Road and traffic counts at selected positions.	Visual evaluations of each road with some instrument measurements. Traffic counts cover entire road network on a regular basis.	Integrated visual and instrument evaluations taken at defined frequencies. Historical traffic counts used to project future traffic.	Condition and usage data are used to determine excess user costs and to predict future excess user costs and related risks.
Decision support	Judgement of future condition and departmental priorities.	Decisions based on reliable strategies and rankings based on condition and importance.	Optimisation used to adapt strategies and improve returns on rehabilitation expenditure.	Optimisation based on historical performance and performance predictions.
Management plans	Minimal information on planned service levels and future expenditure forecasts.	Impacts of plans shown for future service levels with basic information on expenditure forecasts.	Plans demonstrate achievement of objectives and likely service levels subject to budget constraints.	Plans integrated with service expectations. Risk analysis and trade-offs related to budget constraints.
Feedback loop	Anecdotal feedback of performance of actions.	Performance measured as part of ongoing condition evaluation and linked to strategy.	Activities to assess performance and risk feeds into prediction models and tactics.	Regularly measured performance of all actions integrated into prediction models and actions.

Source: Committee of Transport Officials, 2013.

The minimum standards set by COTO (2013) required the provincial road departments and larger municipal authorities to achieve a proficient maturity level by 2015, while the smaller municipalities need only have reached an initiative maturity level by 2014. TRH 22 specifies that high levels of road asset management are optional and can only be implemented when the road authority has the necessary resources available to sustain such systems. The typical timeframe to develop from the initiative to excellence level of road asset management is 10-years (Committee of Transport Officials, 2013).

4.1.1 SANRAL's road asset management capability

SANRAL practices the most advanced road asset management in South Africa, achieving the highest level of maturity. To perform at this level SANRAL (2017) relies heavily on human resources, with the staff complement growing by 11.0% from 314 employees in 2015/16 to 349 in 2016/17. These staffing figures include a large proportion of dedicated specialist personnel that provide SANRAL with the necessary expertise and capacity to manage road investment, network planning, project management, and asset management systems.

In 2016 the Top Employers Institute awarded SANRAL Top Employer certification for the third consecutive year (SANRAL, 2017). This certification is an independently audited global evaluation process focused on employee conditions, including the company's approach to learning and development, talent strategy, workforce planning, performance management, on-boarding processes, and compensation and benefits. SANRAL thus has a superior ability to retain staff, which is evident through the low voluntary staff turnover of 2.5% per annum.

SANRAL has placed significant emphasis on employee skills development. For example, in 2016/17 there were 5, 15, and 31 staff members who respectively achieved a certificate, undergraduate diploma or degree, and post-graduate diploma or degree through the support of an internal bursary (SANRAL, 2017). SANRAL also established a Technical Excellence Academy in 2014 to offer graduate engineers the necessary training and mentorship to register in one of the professions governed by the Engineering Council of South Africa. The annual graduate intake is 27 candidate engineers, but SANRAL has plans to rapidly increase this figure (SANRAL, 2017).

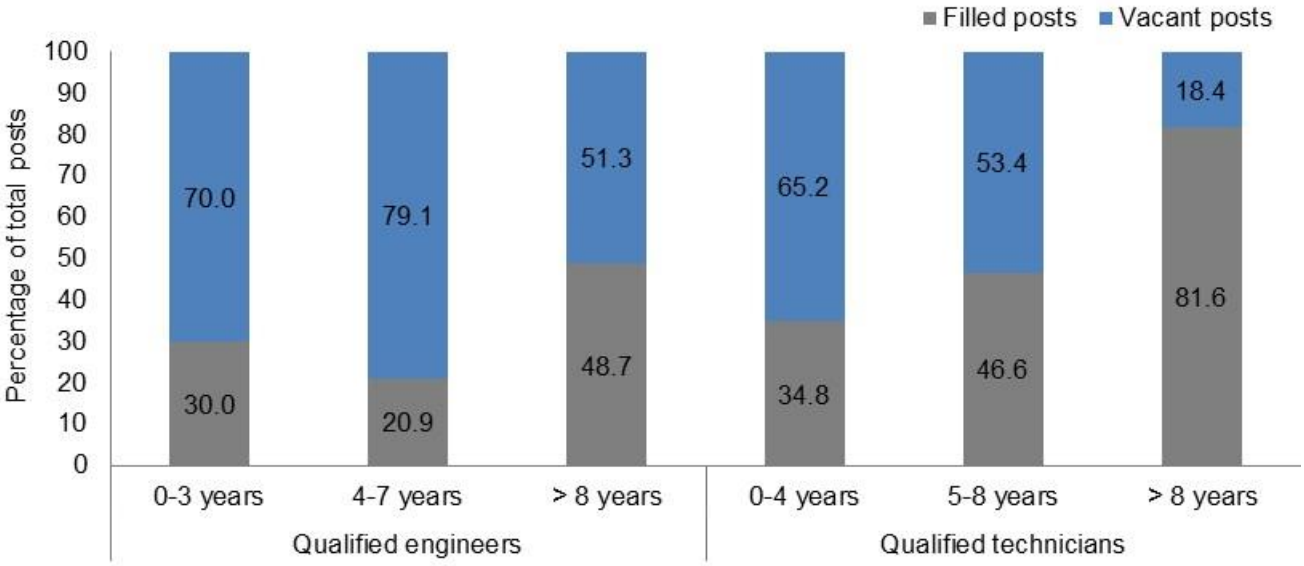
4.1.2 The employment and skills profile within sub-national road authorities

Provincial and municipal authorities, however, are severely affected by the chronic shortage of appropriate managerial and technical skills in the public road sector. Although these road authorities outsource much of the design, construction, maintenance, monitoring, and quality control work for road infrastructure, many are reliant on a diverse range of technical capacity to effectively plan, schedule, and manage their road investment activities. This situation is reflected by the lower levels of asset management, which generally range between initiative and proficient levels of maturity, with some local governments still below the initiative level. In terms of decision support in Table 4.1, this suggests that at best only a minimum level of road investment prioritisation currently takes place.

Mitchell (2014) traces the large-scale departure of qualified road engineers and construction personnel from the public road departments since the early 1960s, when more than 90.0% of road engineering, construction, and maintenance was done by departmental personnel. This figure dropped to 25.0% by 1976, with almost all road engineering, construction, and maintenance now performed by the private sector. This trend was partly motivated by the Public Service Commission’s inability to compensate road professionals according to the level of private sector salaries and their level of responsibility. Additional contributing factors include early retirement packages taken by older, experienced engineers and employment agendas that were implemented by sub-national road departments without due recognition of the required time to transfer knowledge from existing staff (National Treasury, 2018a).

The Department of Cooperative Governance (2016) drafted Local Government Frameworks for Occupational Streams that are expected to form part of the Local Government Municipal Staff Regulations. Planning, design, construction, operation and maintenance, and project management are listed in these frameworks as key technical competencies for engineers. Within these tasks, senior engineers are responsible for master planning, selecting between projects, and initiating operation and maintenance activities. Mid-level and junior engineers are respectively responsible for monitoring and managing projects and systems. Figure 4.1 is based on a 2006 survey undertaken by the National Treasury in five of the nine provinces (Eastern Cape; Free State; Gauteng; Limpopo; and Northern Cape) and illustrates the gap in suitably experienced staff within the provincial road sector (Amusa *et al*., 2011). The data indicates that provincial road authorities have struggled to both retain experienced staff and attract new technical staff. The vacancy rates for junior, mid-level, and senior engineering positions were at 70.0%, 79.1%, and 51.3%, respectively. The situation is better for qualified technicians, but still well below optimal with an average vacancy rate across the three levels of 51.7%. The survey also highlighted that provincial departments were not fully benefiting from the technical skills of the remaining senior engineers as many were either occupied by management roles or much of their time was consumed by junior level work.

Figure 4.1: Vacancy rates in the provincial roads sector, 2006

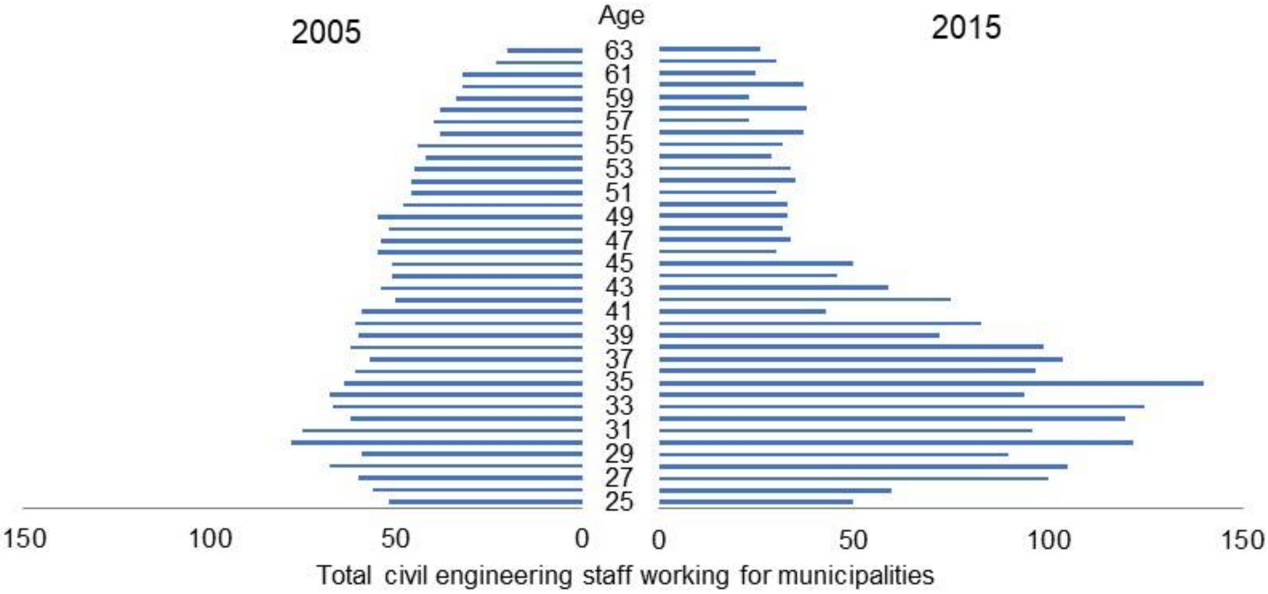


Source: Amusa *et al.*, 2011.

While the data for Figure 4.1 is somewhat outdated, the 2017 provincial RAMPs confirm that capacity and skills within the provincial road departments remains a notable challenge. For example, five of the seven senior management positions in the Eastern Cape Department of Roads and Public Works (2017) were vacant, the KwaZulu-Natal Department of Transport (2017) had a shortfall of 8 managers, 20 engineers, and 42 technicians, and the Western Cape Department of Transport and Public Works (2017) had 19 vacant posts for engineers and 55 vacant posts for other technical professionals. This situation is well summarised by the Eastern Cape Department of Roads and Public Works (DRPW) (2017) who state: “Over an extended period, the DRPW has found it increasingly difficult to retain or recruit technical staff at supervisory and mid-management levels. This has resulted in a huge gap in suitably experienced staff, an inability to adequately transfer skills to our young bursary technicians and an over reliance on consultants”. The National Treasury (2018a) are strongly against the reliance of road departments on the private sector to manage their road investments.

The same 2006 survey also indicated that the average age for engineers in the public roads sector was 50 years (Amusa *et al*., 2011). This aged skilled workforce becomes an issue given the high vacancy rates for junior and mid-level staff. These two factors combined mean that many of the technical skills have not been fully transferred from senior to junior officials before the former cohort retires. While Figure 4.2 indicates a welcome shift with an influx of junior engineers into the industry, the responsibility to manage, supervise, and train this growing group of inexperienced staff falls to the limited number of experienced professionals that remain in the public sector (Lawless, 2017).

Figure 4.2: Population pyramid of all municipal civil engineering staff, 2005 vs 2015



Source: Lawless, 2017.

Lawless (2017) shows that capacity in South African municipalities was too low in 2015 to deliver, operate, and maintain local government infrastructure. The number of municipalities with zero and one civil engineering staff member respectively fell from 82 and 60 in 2005 to 28 and 41 in 2015. Although this is an improvement, the number of incapacitated municipal road authorities is still significant. Moreover, most of the engineers over 50 years old work in the metropoles with very few in the district and local municipalities. The NDOT (2006) also noted that engineering vacancy rates in municipalities can run up to 60.0%. The reality in 2015 was that the oldest engineering staff member was 44 years or younger in half of the municipalities and 34 years or younger in 45 of the municipalities.

The result of this skills shortfall is that many municipal road authorities rely on junior staff members, who due to their inexperience often base road investment schedules on demands from councillors or public complaints rather than meaningful long-term planning (Lawless, 2017). Few sub-national road authorities, especially municipalities, therefore have well-developed road management information systems. Without this data many road authorities have limited information on which to base their road investment and needs identification processes. Furthermore, this limits the ability of road authorities to find alternative ways to operate, improve, and extend the road network (National Department of Transport, 2018a). The NDOT (2018) has acknowledged the dire state of technical capacity within the sub-national road departments and the adverse effect this has had on road investment. Although the NDOT has now committed, amongst other interventions, to develop a national guideline and staffing strategy for road authorities, any turnaround will take significant time given the magnitude of lost skills and is likely to be hampered by budget constraints and the current moratorium on public-sector staff hires and promotions.

4.2 THE ROAD MAINTENANCE BACKLOG

The estimated road maintenance backlog accounts for the capital expenditure required for rehabilitation to strengthen paved and gravel roads with a VCI score of very poor (< 35) and poor (35 - 50). The modelled scenarios include a technical needs backlog, which lowers the proportion of roads in poor and very poor condition to 0.0% of the network, and a functional backlog that lowers the proportion of roads in poor and very poor condition to 10.0% of the network. This approach follows that used by COTO (2014) and reflects the NDOT's (2006; 2018a) decision to adopt as the sector's performance indicator the international benchmark that no more than 10.0% of the road network should be in a poor and very poor condition.

4.2.1 <u>Methodology and parameters</u>

The methodology to estimate the road maintenance backlog at a network level is based on developing country and World Bank (2005b) practices, TRH22 (COTO, 1996), and a similar study by COTO (2014) for 2013. The common practice is that the maintenance backlog should cover assets that have deteriorated beyond routine or periodic maintenance, which according to Table 4.2 are the road segments in poor or very poor condition. Roads in a

“Fair” or better condition are excluded from the road maintenance backlog as these are still fully functional assets.

Table 4.2: Road categories and conditions

Category	VCI Range	Condition
Very good	85 – 100	Road is well constructed and maintained. It will have a residual life of around 15 years with no further maintenance, or an indefinite life with proper maintenance.
Good	70 – 85	Road is well constructed and maintained. It will have a residual life of around 8 years with no further maintenance, or an indefinite life with proper maintenance.
Fair	50 – 70	Road shows some signs of deterioration but can be returned to “Good” condition if proper maintenance is done immediately.
Poor	35 – 50	The road has failed and extensive maintenance is immediately required for it to be salvaged.
Very poor	0 – 35	The road can no longer be maintained and needs major reconstruction to return it to a “Good” state.

Source: Automobile Association SA, 2008.

South African road authorities use the condition index trigger method to group roads into maintenance categories (COTO, 1996). This method assigns a specific maintenance action once the condition index for a road, in this case VCI, drops below a specific limit. Roads in poor and very condition trigger a rehabilitation event. This does, however, assume that roads in poor and very poor condition can be recovered through rehabilitation and do not require reconstruction. Instances where reconstruction is required will escalate the estimated road maintenance backlog.

An aggregate cost matrix is produced based on specific road categories. The 372 723 km of roads in poor and very poor condition fall within one of 48 road categories, which are determined according to 5 variables with 11 possible outcomes: road ownership status (proclaimed or unproclaimed); road surface (paved or gravel); traffic volume (low, medium, or high); topographic conditions (flat or steep terrain); and climate zone (dry or wet climate). An average cost in Rand/km to rehabilitate poor and very poor condition roads is assigned to each road category according to the local conditions. The aggregate backlog cost is then simply the matrix product of the total km of poor and very poor condition roads in each category and the cost to rehabilitate each such km. The following sub-sections disaggregate poor and very poor condition roads between these categories and set the parameters for the average rehabilitation costs.

4.2.1.1 *The distribution of road traffic*

The cost of road works is sensitive to traffic volumes. The volume and type of road traffic determines the required bearing capacity, which in-turn informs the road's cross-section and surface type. Given non-trivial differences in traffic volumes between and within each authority's road network and the fact that the cost to rehabilitate a high-volume paved road can be almost double a medium-volume paved road, it is problematic that the 2013 road maintenance backlog estimated by COTO (2014) applied one rehabilitation cost to all national and provincial roads and a separate flat rehabilitation cost to metropolitan and district municipality roads.

Table 4.3 disaggregates the provincial paved and gravel roads into three traffic categories: low-volume; medium-volume; and high-volume. The Average Annual Daily Traffic (AADT) thresholds, which are different for paved and gravel roads, are based on the reporting style of the RAMPs and the traffic categories used by the National Treasury (2018a). The average was applied to provinces with missing data and variations in the reported AADT categories required some approximations. Whereas COTO (2014) assumed that all provincial paved roads carry high traffic volumes, the data shows that 30.0% and 26.0% of paved provincial roads had AADT less than 500 and 2 000 vehicles, respectively. In terms of provincial gravel roads, 84.0% were low-volume and only 8.0% were high-volume. The NDOT's (2017b) RRAMS data provides the following aggregated traffic statistics for the district municipality paved and gravel roads: 95.4% low-volume; 3.8% medium-volume; and 0.8% high-volume.

Insufficient traffic data required two assumptions: all national roads are high volume; and the metropolitan traffic profile reflects the provinces. The assumption about the metropolitan traffic volumes, which is more uncertain than that for national roads, was cross-checked against the traffic congestion levels in the metropolitans and the City of Cape Town's traffic distribution report (COTO, 2014; Western Cape Government, 2018).

Table 4.3: Traffic volume distributions on provincial roads, 2017

	AADT Category					
	Low-volume		Medium-volume		High-volume	
	Gravel	Paved	Gravel	Paved	Gravel	Paved
Authority	**0 - 249**	**0 - 499**	**250 - 499**	**500 - 1 999**	**> 500**	**> 2 000**
Eastern Cape	60%	39%	20%	43%	20%	18%
Free State	96%	35%	2%	15%	2%	50%
Gauteng	70%	5%	22%	18%	8%	77%
KwaZulu-Natal	84%	15%	8%	20%	8%	65%
Limpopo	84%	30%	8%	26%	8%	44%
Mpumalanga	84%	30%	8%	44%	8%	26%
North West	93%	33%	5%	34%	2%	33%
Northern Cape	95%	61%	1%	10%	4%	29%
Western Cape	93%	36%	6%	29%	1%	35%
Total	**84%**	**30%**	**8%**	**26%**	**8%**	**44%**

Source: Eastern Cape Department of Roads and Public Works, 2017; Free State Department of Police, Roads and Transport, 2017; Gauteng Department of Roads and Transport, 2017; KwaZulu-Natal Department of Transport, 2017; Mpumalanga Provincial Government, 2016; North West Department of Public Works and Roads, 2016; Northern Cape Department of Roads and Public Works, 2017; Roads Agency Limpopo, 2017; Western Cape Department of Transport and Public Works, 2017.

4.2.1.2 *The volume of deteriorated roads*

Only 11.0%, or 2 442 km, of the 22 197 km national road network was in a poor and very poor condition in 2017 (SAICE, 2017). SAICE (2017) note SANRAL's success in preserving the network in a relatively good condition when scoring national roads a "B" (fit for the future) in the 2017 Infrastructure Report Card. The 1.0%, or 222 km, deviation in the volume of poor and very poor condition national roads from the 10.0% benchmark is attributed by SAICE (2017) to the inclusion of poorer condition provincial roads in the national road network.

SAICE (2017) scored provincial paved roads a "D" (at risk of failure) and gravel roads an "E" (unfit for purpose) in the 2017 Infrastructure Report Card. The data presented in Table 4.4 indicates that 32.2%, or 15 729 km, of provincial paved roads and 55.6%, or 96 703 km, of provincial gravel roads were in poor and very poor condition in 2017. Compared to 10.0% benchmark an additional 10 834 km of paved roads and 79 330 km of gravel roads were in a poor and very poor condition.

Table 4.4: VCI category of provincial paved and gravel roads, 2017

Authority	Surface	VCI category				
		Very poor	Poor	Fair	Good	Very good
Eastern Cape	Gravel	11 240	13 114	9 367	2 997	749
	Paved	227	1 350	1 373	824	8
Free State	Gravel	4 306	9 004	9 396	9 004	7 438
	Paved	2 102	2 102	1 720	382	64
Gauteng	Gravel	0	448	894	16	0
	Paved	29	343	1 234	969	1 109
KwaZulu-Natal	Gravel	907	13 037	9 827	662	74
	Paved	569	2 357	2 764	1 300	1 138
Limpopo	Gravel	5 000	7 143	2 143	0	0
	Paved	149	633	1 075	1 601	2 515
Mpumalanga	Gravel	0	5 122	2 687	588	0
	Paved	328	1 529	1 911	1 146	546
North West	Gravel	13 634	1 026	0	0	0
	Paved	2 030	589	800	1 092	615
Northern Cape	Gravel	475	7 837	12 111	2 612	712
	Paved	36	468	1 153	1 153	792
Western Cape	Gravel	467	3 943	4 624	945	183
	Paved	136	750	1 978	2 455	1 500
Total	**Gravel**	**36 030**	**60 673**	**51 048**	**16 825**	**9 157**
	Paved	**5 607**	**10 122**	**14 007**	**10 923**	**8 287**

Source: Eastern Cape Department of Roads and Public Works, 2017; Free State Department of Police, Roads and Transport, 2017; Gauteng Department of Roads and Transport, 2017; KwaZulu-Natal Department of Transport, 2017; Mpumalanga Provincial Government, 2016; North West Department of Public Works and Roads, 2016; Northern Cape Department of Roads and Public Works, 2017; Roads Agency Limpopo, 2017; Western Cape Department of Transport and Public Works, 2017.

COTO (2014) and SAICE (2017) indicate the historical challenge with procuring municipal road condition data. The condition profile for metropolitan roads presented in Table 4.5 is based on the dataset used by COTO (2014) to estimate the road maintenance backlog in 2013, with the exception that the paved road data for the City of Johannesburg was updated with the 2017 statistics published by the Johannesburg Road Agency (2017). Considering that some of the metropolitan VCI samples are from as early as 2004, COTO (2014) acknowledge that the network conditions are likely to have deteriorated. Unfortunately, the updated road condition data collected by the other metropolitans has not been released but involved parties, such as SAICE, have questioned the credibility and consistency of the data.

Unlike the limitations faced in previous backlog studies, for example COTO (2014) relied on a 0.7% sample of municipal gravel roads, the condition of the district municipality roads was sourced from the NDOT's (2017b) 2017 RRAMS database. The RRAMS data covers 40 of the 44 district municipalities, with 203 052 km of road condition data.

Table 4.5: VCI for municipal paved and gravel roads, 2017

Authority	Surface	Very poor	Poor	Fair	Good	Very good
Metropolitans	Paved	2.5%	7.4%	18.5%	38.5%	32.9%
	Gravel	1.3%	7.2%	2.8%	88.5%	0.2%
District municipalities	Paved	6.9%	15.4%	39.3%	33.9%	4.5%
	Gravel	41.3%	49.7%	7.1%	1.5%	0.4%

Source: COTO, 2014; Johannesburg Road Agency, 2017; National Department of Transport, 2017b.

SAICE (2017) scored paved metropolitan roads a "C-" (satisfactory for now) and paved municipal roads a "D-" (at risk of failure) in the 2017 Infrastructure Report Card. According to the condition profiles in Table 4.5, there were 5 117 km of metropolitan and 9 065 km of district municipality paved roads in poor and very poor condition in 2017. This metropolitan backlog is within the acceptable benchmark of 10.0%, while the district municipality backlog exceeds this limit by 5 000 km.

SAICE (2017) scored gravel roads an "E" (unfit for purpose) in the 2017 Infrastructure Report Card, which matches the higher proportion of poorer condition gravel roads in Table 4.5. According to these statistics 242 439 km of district municipality gravel roads were in poor and very poor condition in 2017. While the 1 229 km of metropolitan gravel roads in poor and very poor condition is within the acceptable benchmark of 10.0%, the volume of deteriorated district municipality gravel roads exceeds this benchmark by 215 797 km.

Because authorities are not able to legally spend public funds on unproclaimed roads, the full 131 919 km network will inevitably be in a very poor condition unless some roads have been privately maintained (National Treasury, 2011). The NDOT's (2018a) policy stance that unproclaimed roads should be assigned to a provincial or municipal authority depending on the classification and significance of the road means that this network poses a contingent maintenance liability to the sub-national road authorities.

The 2017 road maintenance backlog statistics, which correspond with L_{n_x} in Equation 4.1, are shown in Table 4.6. The functional backlog reflects the excess volume of roads in poor and very poor condition compared the 10.0% benchmark, while the technical needs backlog reflects the total volume of roads in poor and very poor condition. These versions of the road maintenance backlog are disaggregated according to the authority, with unproclaimed roads grouped separately.

Table 4.6: The volume of road maintenance backlogs, 2017

	Functional backlog (km)		Technical needs backlog (km)	
Authority	**Paved roads**	**Gravel roads**	**Paved roads**	**Gravel roads**
National	222	N/A	2 442	N/A
Provincial	10 834	79 330	15 728	96 703
Metropolitan	0	0	5 117	1 229
District municipality	5 000	215 797	9 065	242 439
Unproclaimed	N/A	N/A	N/A	131 919
Total	**16 056**	**295 127**	**32 352**	**340 371**

Source: Own calculations.

The 2017 technical needs backlogs shown in Table 4.6 are 203 km, 427 km, and 2 572 km above the 2013 estimates reported by COTO (2014) for the national, provincial paved, and provincial gravel road networks, respectively. The upward revision in the volume of poor and very poor condition national roads is due to the 794 km extension to SANRAL's network, which mostly comprised deteriorated provincial roads. The increase in the provincial road maintenance backlogs since 2013 is due to a combination of growth in both the paved and gravel road networks and a deterioration in the quality of provincial paved roads.

The most notable differences between the technical needs backlogs in Table 4.6 and the 2013 figures published by COTO (2014) are for metropolitan and district municipality roads. Updating the 2013 metropolitan data with the 2017 Johannesburg Road Agency (2017) data increases the volume of metropolitan paved roads in poor and very poor condition from 1 658 km in 2013 to 5 117 km in 2017. COTO (2014) admit that the 2013 estimate for was "a very optimistic view", but continued poor performance by many of the metropolitan road departments suggests that 5 117 km may still be an underestimate. Moreover, the 2013 profiles for district municipality paved and gravel roads were based on non-representative network samples of 28.8% and 0.7%, respectively. Based on these samples the proportion of district municipality paved and gravel roads in poor and very poor condition were 3.6% and 28.54%, respectively. The 2017 RRAMS data, which capture the road condition data for 40 of the 44 district municipalities, revise the proportion of poor and very poor condition district municipality roads upwards to 22.3% for paved roads and 91.0% for gravel roads.

The maintenance backlog for paved roads has therefore grown from 20 561 km in 2013 to 32 352 km in 2017 (COTO, 2014). COTO (2014) also only accounted for 181 602 km of poor and very poor condition gravel roads in 2013, whereas the updated information sets this backlog at 340 371 km. The maintenance backlog profiles in Table 4.7 were generated by applying each authority's traffic distribution to their respective maintenance backlog volume.

Table 4.7: Distribution of poor and very poor condition roads according to traffic volumes, 2017

		Functional backlog (km)			Technical needs backlog (km)		
		AADT category			AADT category		
Authority	**Surface**	**Low**	**Medium**	**High**	**Low**	**Medium**	**High**
National	Paved	0	0	222	0	0	2 442
	Gravel	N/A	N/A	N/A	N/A	N/A	N/A
Provincial	Paved	3 250	2 817	4 767	4 718	4 089	6 920
	Gravel	66 637	6 346	6 346	81 231	7 736	7 736
Metropolitan	Paved	0	0	0	1 535	1 330	2 251
	Gravel	0	0	0	1 032	98	98
District municipality	Paved	4 770	190	40	8 648	344	73
	Gravel	205 870	8 200	1 726	231 287	9 213	1 940
Total	**Paved**	**8 020**	**3 007**	**5 029**	**14 902**	**5 764**	**11 686**
	Gravel	**272 508**	**14 547**	**8 073**	**313 550**	**17 047**	**9 774**

Source: Own calculations.

4.2.1.3 *Road works costs*

Traffic volumes are a major determinant of the road profile and thus the cost of road works. The standard road profiles shown in Table 4.8 are derived from TRH 4 (COTO, 1996), the Western Cape Government's (2006) Geometric Manual, and National Treasury's (2018a) Road Network Cost Model. Higher volume roads are associated with a wider cross-section, added bearing capacity provided by a stronger pavement structure, and thicker and more durable road surfaces. The profile for low-volume roads was modelled on Class 3 and 4 roads given their high representation amongst this network. Future studies, however, should address gravel tracks, paths, and single-lane roads separately if the data is available.

Table 4.8: Standard road profiles

AADT	Cross-section	Design bearing capacity
Low	8.6 metres	0.1 - 0.3 million equivalent standard axles
Medium	9.8 metres	0.3 - 3.0 million equivalent standard axles
High	12.4 metres	3.0 - 100.0 million equivalent standard axles

Source: COTO, 1996; Western Cape Government, 2006; National Treasury, 2018a.

The average unit costs to rehabilitate or upgrade these roads are presented in Table 4.9, considering the same AADT categories used in Table 4.3. The baseline costs are taken from the National Treasury’s (2018a) Road Network Cost Model and reflect the cost of road works in an area with mostly flat topography (gradient < 3.0%) and relatively dry conditions. The cost to rehabilitate national roads was sourced from the maintenance backlog study by COTO (2014) as their cost for SANRAL’s roads was based on calculations of average actual costs considering traffic, climate, and terrain. Annual roadwork inflation data was used to convert the 2013 cost for national roads into 2017 terms (Statistics South Africa, 2018a).

Table 4.9: Per km unit costs for road rehabilitation and upgrades, 2017

Road works activity	Low-volume	Medium-volume	High-volume	National roads
Rehabilitation of a paved road	R2 100 000	R3 680 000	R6 300 000	R8 939 792
Rehabilitation of a gravel road	R800 000	R840 000	R1 010 000	N/A
Gravel to surface upgrade	R3 500 000	R4 030 000	R6 410 000	N/A

Source: National Treasury, 2018a; COTO, 2014; Own calculations.

Although COTO (2014) list the per km replacement cost for national and provincial paved roads at R18.4 million and R9.7 million, respectively, their 2013 road maintenance backlog estimate applied a single flat unit cost of R8.5 million per km for paved road rehabilitation to both networks. This cost assumes that provincial roads are specified for high traffic volumes that match the national road network, which was disproved in Section 4.2.1.1. This same assumption was carried through by COTO (2014) to metropolitan and district municipality paved roads, with per km rehabilitation costs of R5.0 million and R3.0 million, respectively. Given that a high proportion of provincial and district municipality paved roads carry low traffic volumes, this assumption overestimates the maintenance backlog for paved roads.

Furthermore, the 2013 road maintenance backlog study by COTO (2014) applied a unit cost of R200 000 per km to rehabilitate provincial, metropolitan, and district municipality gravel roads. This cost, which is aligned with mid-life minor rehabilitation activities in the National Treasury's (2018a) Road Network Cost Model, is significantly lower than those in Table 4.9 and any of the figures in the provincial RAMPs and tender documents assessed as part of the Provincial Roads Performance and Expenditure Review (National Treasury, 2018a). The expectation is that gravel road rehabilitation will provide a 150 mm layer of G10 gravel to lift the road into a very good condition, rather than a top-up to the average minimum gravel thickness of 60 mm required to be in fair condition (Western Cape Government, 2017).

The gravel to surface upgrade costs reported by the provincial road departments provides an example of the reporting and costing challenges within the sector. These challenges, in combination with the issues raised around COTO's (2014) 2013 road maintenance backlog study, help to explain why this re-estimation of the road maintenance backlog is necessary. The unit cost for gravel to surface upgrades reported in the RAMPs ranged from R347 200 per km in North West province to R11.4 million per km in Mpumalanga province (North West Department of Public Works and Roads, 2016; Mpumalanga Provincial Government, 2016). These unit costs are disjoint from those in Table 4.9 and COTO's (2014) estimate of R6.0 million per km. Many of the inflated gravel road upgrade costs are due to under-resourced departments substituting low-volume seals for 30-40 mm asphalt surfaces on low-volume roads to minimise the life-cycle maintenance regime. These examples of overcapitalisation have distorted the accuracy of the self-reported road maintenance backlog estimates.

4.2.1.4 *Environmental factors*

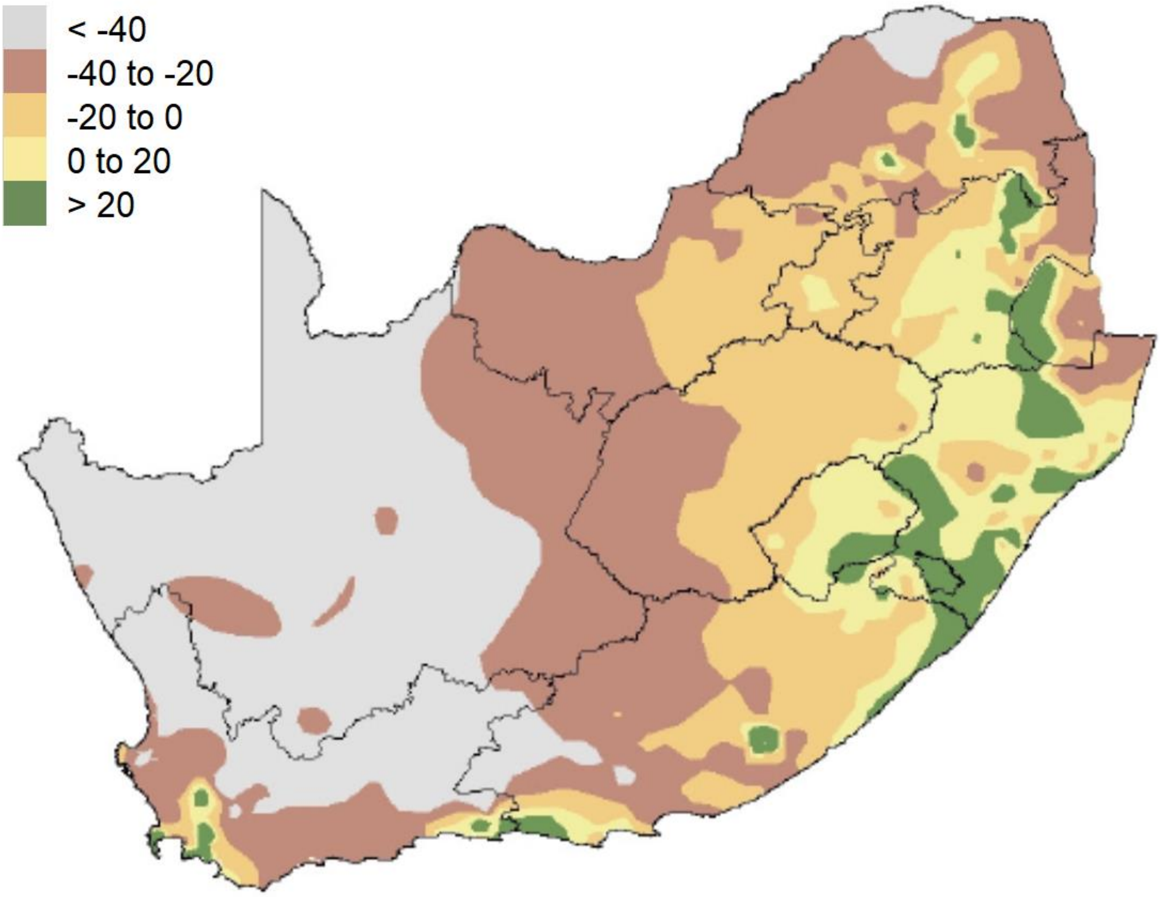
Table 4.10 lists the associated environmental cost premiums over-and-above the standard unit costs in Table 4.9. Extreme moisture, scoring more than 20 on Thornthwaite's Moisture Index, has a significant effect on road work costs. Moist conditions require measures such as additional subsoil drains, the replacement of G1 bases with asphalt, and a layer of rock fill to stabilise the road foundation. Steep road gradients also affect road rehabilitation and upgrade costs. TRH 22 classifies a road as mountainous if the gradient is above 7.0% and there are many sags and crests (Committee of Transport Officials, 2013). TRH 3 (Committee of Transport Officials, 2007) explains that the traction force of vehicle tyres on steep road gradients may result in flushing or deboning and slippage of the road surface. In addition to segmented block paving or concrete to cope with steep road gradients, the canalized water flows in areas with a steep gradient necessitates additional paved side drains.

Table 4.10: Roadwork cost premiums for wet climates and steep road gradients

Roadwork activity	Region	Low-volume	Medium-volume	High-volume
Gravel road rehabilitation	High moisture	25.0%	25.0%	69.7%
	Steep gradient	50.0%	50.0%	67.3%
Paved road rehabilitation	High moisture	20.0%	20.0%	20.0%
	Steep gradient	35.0%	30.0%	30.0%
Gravel to surface upgrade	High moisture	60.0%	60.0%	49.0%
	Steep gradient	58.0%	50.4%	31.8%

Source: National Treasury, 2018a.

Figure 4.3: Thornthwaite's Moisture Index



Source: Committee of Transport Officials, 2013.

Thornthwaite's Moisture Index for South Africa is presented in Figure 4.3. The Council for Geoscience (2011) note that approximately 6.0% of South Africa has more than 1 000 mm of rainfall per year, with most of the high moisture areas in the country's eastern escarpment, KwaZulu-Natal province, and to a lesser degree Eastern Cape and Western Cape provinces.

The Mpumalanga Department of Public Works, Roads and Transport's (2016) inventory indicates that 36.9% of the province's road network is affected by a wet climate. This figure seems high in comparison to Figure 4.3, but there may be a high concentration of roads in the affected areas. Unfortunately, similar data was not available for the other provinces.

In light of the prevalence of high moisture areas in the Mpumalanga and KwaZulu-Natal provinces, the 36.9% was applied for this study to the volume of poor and very poor condition provincial roads in Mpumalanga and KwaZulu-Natal, the proportion of total poor and very poor condition district municipality paved roads in KwaZulu-Natal (14.3%) and Mpumalanga (15.3%), and the proportion of total poor and very poor condition district municipality gravel roads in KwaZulu-Natal (12.0%) and Mpumalanga (10.6%) (National Treasury, 2018a). No assumption was made for roads in the Eastern or Western Capes due to a lack of data. This introduces a conservative bias into the road maintenance backlog estimate and should be addressed in follow-up studies should the information become available.

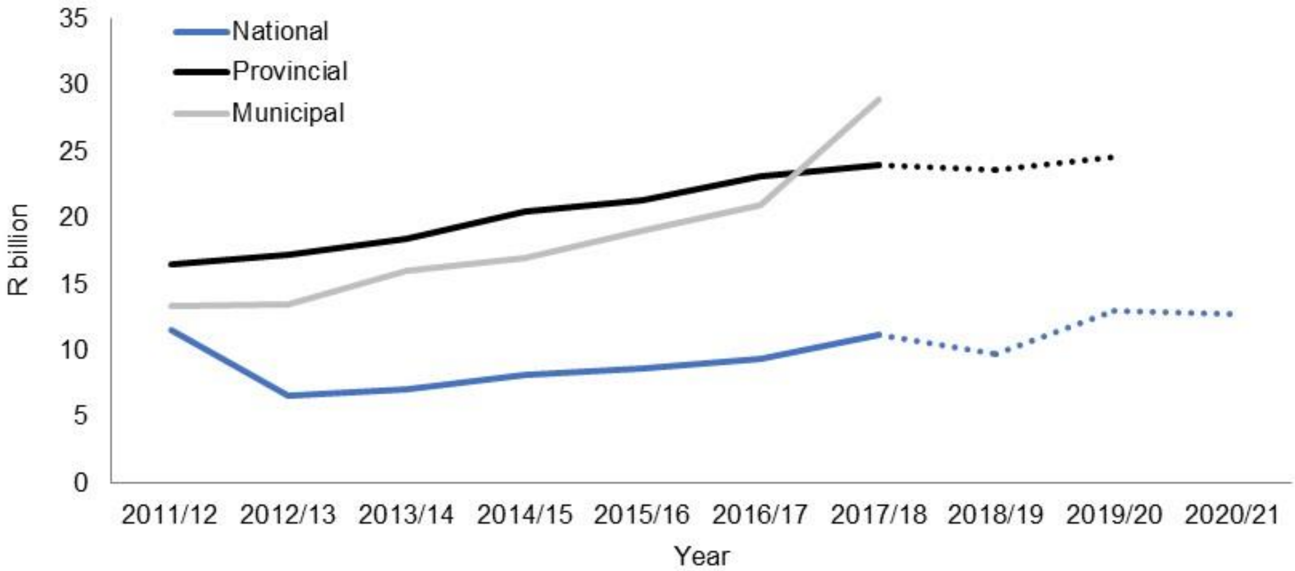
There are more than 60 mountain ranges across South Africa, with generally low but varying road densities in these areas. This makes it difficult to identify the volume of roads affected by steep gradients. Although this factor will have an upward effect on the estimated road maintenance backlog, this too is excluded from this study due to the high level of uncertainty.

4.2.2 Road maintenance backlog results

Section 4.2.1 provides the necessary information to estimate the road maintenance backlog in 2017 according to the administrative road classes: national; provincial; metropolitan; district municipality; and unproclaimed. It is important to contextualise the results within the available road maintenance funding envelopes. Figure 4.4 shows the trends and estimates in road maintenance expenditure by each authority.

National road maintenance spending includes the following capital transfers and subsidies from the national fiscus to SANRAL: Non-toll network; Coal haulage road network; Other. The transfers and subsidies are intended for the maintenance of the non-toll road network, which comprised 87.0% of SANRAL's network in 2017 (SANRAL, 2017). The remainder of the national road network are toll roads, whose maintenance is covered by user charges.

Figure 4.4: Road maintenance expenditure trends and estimates



Source: National Treasury, 2018b. National Treasury, 2018c.

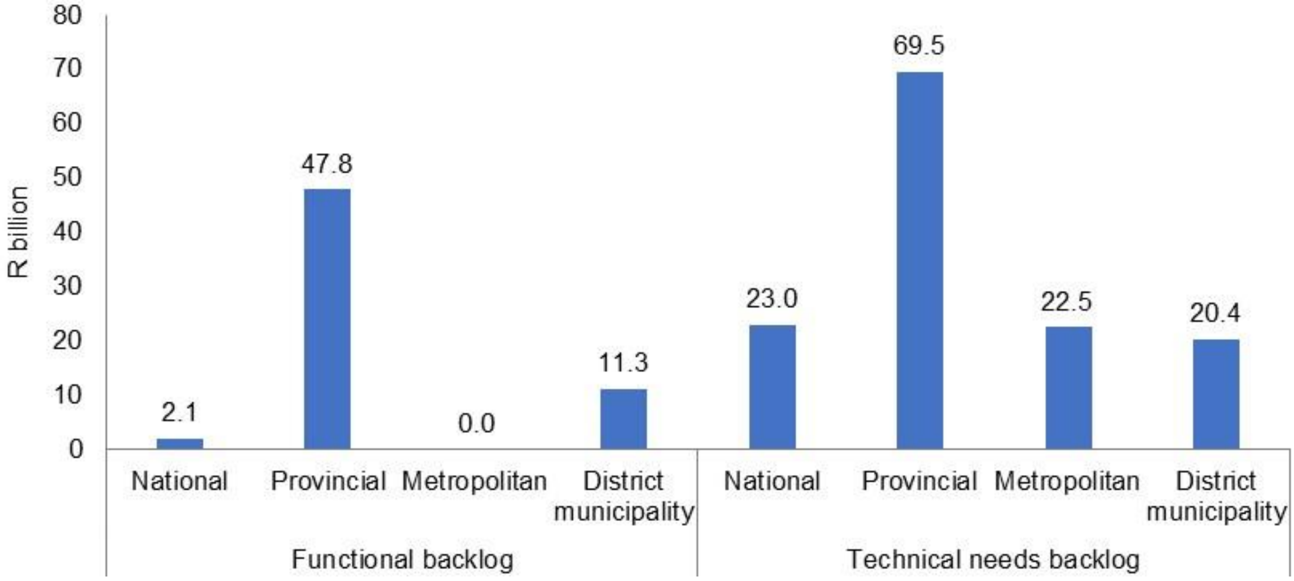
The provincial road transport expenditure in Figure 4.4 captures road maintenance activities funded through a combination of provincial equitable share allocations from the national fiscus, provincial own-revenues, the Provincial Road Maintenance Grant (PRMG), and the Expanded Public Works Incentive Grant. The PRMG is ring-fenced, with its use regulated by the Division of Revenue Act, but the provinces exercise discretion over the amount of equitable share and own-revenues to allocate to road maintenance. The PRMG allocations are formulaically determined according to the extent of the provincial road network, traffic volumes, VCI, and climatic and topographic factors.

Municipalities fund their road maintenance through a combination of the local government equitable share, municipal own-revenues, Municipal Infrastructure Grant, Public Transport Infrastructure and Systems Grant, and EPWP Integrated Grant for municipalities. They also have discretion over the amount of own funds allocated to road maintenance.

4.2.2.1 *Road rehabilitation backlog*

Figure 4.5 shows the cost to rehabilitate paved roads in poor and very poor condition. The total functional backlog and technical needs backlog are R61.2 billion and R135.4 billion, respectively. Although provinces are only responsible for 29.9% of the total paved road network, the significant deterioration of their networks means that they account for 78.1% of the functional backlog and 51.3% of the technical needs backlog.

Figure 4.5: Maintenance backlog for paved roads, 2017

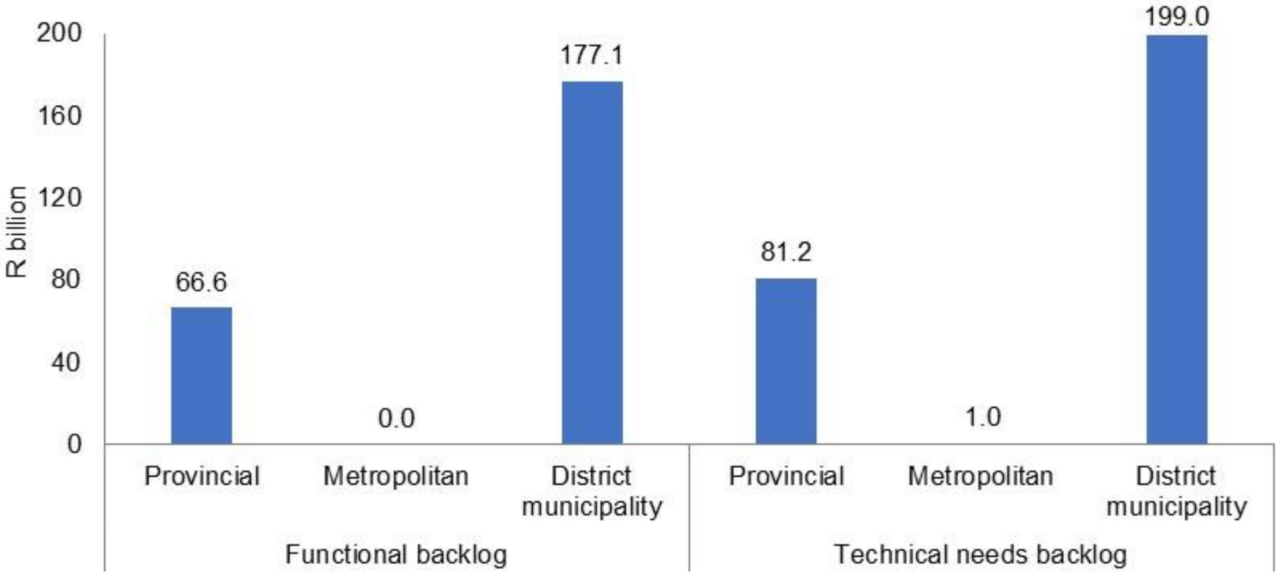


Source: Own calculations.

The maintenance backlogs on national and municipal paved roads appear manageable, with the respective functional backlogs amounting to 5.9% of SANRAL's MTEF non-toll road funding and 39.0% of 2017/18 municipal road transport expenditure. However, the functional and technical needs backlogs for provincial paved roads are 138.0% and 200.7% of the MTEF PRMG allocation, respectively. The PRMG accounts for roughly half of provincial road maintenance expenditure. Very limited resources are therefore available to rehabilitate the provincial paved road network unless the PRMG is significantly grown over the medium to long term or provinces allocate a much larger portion of own funds to road maintenance – ideally a combination of both measures.

Figure 4.6 shows the cost to rehabilitate gravel roads in poor and very poor condition. National roads do not feature as SANRAL only manages paved roads. The total functional backlog is estimated at R243.7 billion, while the technical needs backlog is at R281.2 billion.

Figure 4.6: Maintenance backlog for gravel roads, 2017



Source: Own calculations.

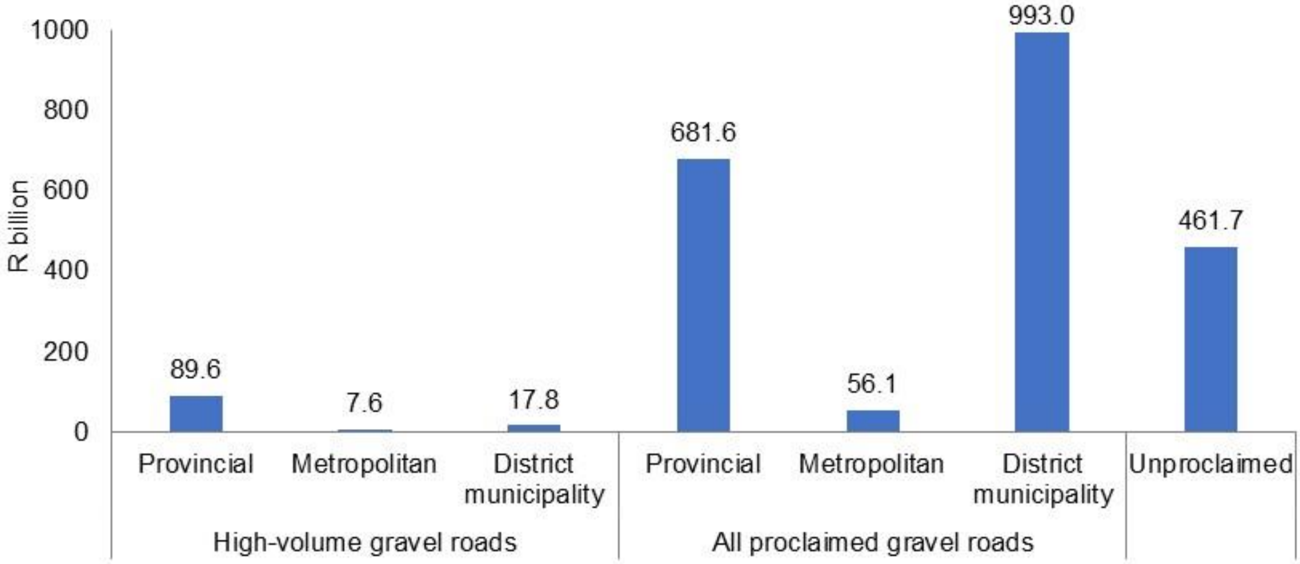
When the paved and gravel road networks are combined the functional and technical needs backlogs for provinces grow to 330.4% and 435.2% of the 2018/19 MTEF PRMG allocation, respectively. Municipalities are also highly distressed with their combined paved and gravel road functional and technical needs backlogs respectively growing to 650.1% and 838.2% of 2017/18 municipal road transport expenditure.

4.2.2.2 *Gravel road surfacing backlog*

Figure 4.7 shows the estimated cost to upgrade high-volume gravel roads (AADT ≥ 500), all proclaimed gravel roads, and unproclaimed gravel roads. The contingent maintenance liability posed by unproclaimed roads is considered due to the NDOT's (2018a) policy position that unproclaimed roads should be assigned to a provincial or municipal authority depending on the classification and significance of the road.

Gravel to surface upgrades for high-volume roads is estimated to cost R115.0 billion, with R89.6 billion lying with provinces. The estimated cost to upgrade all proclaimed gravel roads is R1.7 trillion. If unproclaimed roads are incorporated into the formal road network they should be upgraded rather than rehabilitated as many years of maintenance neglect mean they likely require reconstruction, in which case Chapter 7 argues that light seals are more cost-effective. The unproclaimed road network therefore poses a R461.7 billion contingent liability to the provincial and municipal road authorities, which may escalate depending on the proportion of these roads that are in wet and mountainous regions.

Figure 4.7: Gravel road surfacing backlog, 2017



Source: Own calculations.

4.3 CONCLUSION

The road maintenance backlogs are immense, particularly for the provincial and municipal networks. By the end of 2017 the provincial and municipal road rehabilitation backlogs were approximately 6 and 8 times higher than their respective total annual road maintenance expenditure. The pressures on road maintenance budgets, such as the National Treasury's commitment to fiscal consolidation and crowding-out by other needs such as education and healthcare, are also currently worsening rather than abating (National Treasury, 2018a). In fact, the continued absence of notable economic growth means that the budget deficit must be narrowed through savings and efficiencies in departmental expenditure as seen by the parliamentary approved haircut to the 2018/19 MTEF PRMG allocation (National Treasury, 2018c). These sub-national road maintenance backlogs therefore appear too large to be addressed through national transfers and subsidies.

Stakeholders such as the NDOT and SANRAL are therefore exploring alternative funding sources to help finance the road maintenance backlog. While a well-designed version of the NDOT's (2018a) integrated funding model would relieve some of the funding pressures, it is unlikely to alleviate the funding constraints completely or sooner than the medium to long term for several reasons: many of the provincial road departments note in their RAMPs that neither they, the consulting engineers, nor the contractors have the required resources to handle the significant capital injections needed to address the maintenance backlogs over the short term; the road maintenance backlog is potentially exacerbated by the NDOT's policy position that provinces and municipalities should absorb the 131 919 km of mostly deteriorated unproclaimed roads within their networks; and most of the proposed funding mechanisms are not uniformly applicable across authorities so either some road authorities must remain under-funded or the requisite time must be spent to design and implement ring-fencing and inter-governmental revenue sharing agreements.

One of the main implications of this situation is authorities are forced to prioritise their road investment schedules, with a non-trivial number of projects removed from the in-year, short-term, medium-term, and long-term investment schedules. Over-and-above the possibility of fiscal relief, authorities can mitigate the extent to which investment prioritisation is required by cost-effectively providing road infrastructure and rationalising their road networks. These strategies are therefore respectively developed in Chapters 7 and 8 as core elements of an optimal road infrastructure investment policy for South Africa.

But the extensive road maintenance backlogs mean that a high degree of prioritisation is likely to be required even with optimal road surfacing policy and a rationalised road network. To ensure that the most valuable roads are prioritised authorities must be able to identify the economic contribution of each road. Without this information authorities run a relatively high risk, given the size of the maintenance backlogs, of favouring lower value roads over more valuable alternatives. The method to prioritise road investments cannot be left to the individual road authorities as many sub-national road departments have poor performance records, immature asset management systems, and lack the requisite capacity to handle a task of this magnitude. Moreover, the prevalence of road maintenance backlogs across the jurisdictions means that a uniform prioritisation process is necessary to achieve network level efficiencies. What South Africa therefore requires is a methodology that all authorities can adopt, regardless of the depth of their technical competencies, to consistently prioritise the optimal set of road projects.

5 THE NEED FOR A ROAD INVESTMENT PRIORITISATION MODEL

Chapter 4 detailed the troubling situation faced by the South African road sector, whereby the road networks managed by the incapacitated provincial and municipal authorities have deteriorated to the point where it is impossibly expensive, at least over the medium term, to rehabilitate these networks. Given the resultant need for these sub-national road authorities to prioritise their road investment schedules, this chapter evaluates the relevant revenue allocation processes and set of road investment prioritisation methods to assess their ability to efficiently allocate funding in line with the mandate of the sector to address citizens' basic rights and grow the economy.

Section 5.1 references policy documents to describe the mandate of the South African road sector. These documents are compared to highlight the consistency of this mandate since 1994. Also addressed are the motivations for supplementary policy documents, such as the Road Infrastructure Strategic Framework for South Africa and Rural Transport Strategy, as they link the investment shortfalls with the need for a road investment prioritisation system.

Section 5.2 explores the revenue allocation processes of the sub-national road authorities. The main revenue sources, own-funding and national grants, are assessed to identify their respective weaknesses in terms of the volume and targeting of road budgets. Problems such as the infinitesimal margin are argued to negatively affect the amount of own-revenue that provinces and municipalities allocate to the road sector, while national grant allocations are shown to be misaligned with the mandate of the sector to maximise economic growth.

Section 5.3 evaluates the ability of the local and international road investment prioritisation methods to efficiently allocate the available budgets according to the mandate, considering that this mandate includes a unique constitutional commitment. The approach adopted in this thesis, which is elaborated in Chapter 6, takes it as given that citizens' rights of access to basic services are non-negotiable. This is precisely what makes them 'rights'. The critique therefore reviews whether the prioritisation methods identify and treat basic access services as a constitutional obligation, and therefore not able to be traded-off for economic growth, or whether the methods prioritise basic access services using alternative approaches such as distributional weights or basic needs externalities. These alternative approaches, which are explained by Jenkins *et al.* (2013), may similarly prioritise basic access rights. However, their applications are suited to contexts where access to basic services are motivated by an altruistic disposition of society or social imperatives, rather than a constitutional obligation.

Section 5.4 summarises the analysis, which reaches the same conclusion as the National Treasury (2018a) and National Development Plan (NDP): the provincial and municipal road authorities require a systematic road prioritisation system that accounts for South Africa's constitutional commitment to basic rights and resolves poorly coordinated intergovernmental planning, disconnects across municipal boundaries, and how authorities manage economic growth (National Planning Commission, 2012). The conclusion also clarifies which shortfalls with the prioritisation methods will be addressed in the subsequent chapters of this thesis.

5.1 THE MANDATE OF THE ROAD SECTOR

The 1996 White Paper on National Transport Policy set out the vision for the South African transport sector post-1994: "Provide safe, reliable, effective, efficient, and fully integrated transport operations and infrastructure which will best meet the needs of freight and passenger customers at improving levels of service and cost in a fashion which supports government strategies for economic and social development whilst being environmentally and economically sustainable" (Republic of South Africa, 1996). Within this vision were three core priorities: address citizens' basic rights, develop human capital, and grow the economy.

The Road Infrastructure Strategic Framework for South Africa (RIFSA) provided an updated blueprint for the planning and development of road infrastructure in South Africa (National Department of Transport, 2006). RIFSA built on the 1996 White Paper on National Transport Policy and emphasised that the sector had a dual responsibility to provide adequate access to basic services for marginalised and poor communities in both rural and peri-urban areas and to contribute to growing the economy. In terms of the former responsibility, the Rural Transport Strategy for South Africa was developed in 2007 to highlight and address the inferior access that the transport network afforded rural communities to basic social services (National Department of Transport, 2007). The effect of the apartheid policy of separate development and the subsequent maladministration of the road sector has resulted in the continued physical isolation of many rural communities from basic services.

The 2017 Draft Revised White Paper on National Transport Policy was developed to reflect the progress and current conditions in the sector (National Department of Transport, 2017). While the vision for the sector was reformulated, the new version reconfirms the mandate: "A transport system that provides equitable and reliable access for all in an economically and environmentally sustainable manner to advance inclusive growth and competitiveness of the country". Again, equitable access to basic services and support for economic growth are the focus areas for the sector.

The final policy document that requires reference is the 2018 Draft Roads Policy for South Africa (National Department of Transport, 2018a). This policy draws inspiration from the 1996 White Paper on National Transport Policy, the 2017 Draft Revised White Paper on National Transport Policy, the Constitution, and the NDP in setting the following objectives for the sector: to provide access to social facilities and amenities; to create and provide linkages to economic opportunities; and to mitigate the environmental impacts of roads.

The original mandate set by the 1996 White Paper on National Transport Policy is evident throughout the policy documents, albeit in an updated form and with added emphasis on the physical exclusion of isolated rural communities. The implication of the policy prescriptions is that provision of road infrastructure in South Africa cannot be regarded as purely political, as is it was pre-1994 and is in many other countries. The road authorities are committed by the Constitution to protect second-generation rights, most notably citizens' rights to enjoy a minimum level of access to basic services consistent with fundamental dignity.

5.2 REVENUE ALLOCATION

This section identifies major inefficiencies in the current revenue allocation processes in the sub-national authorities. This analysis indicates that the budget envelopes are negatively affected by problems such as the infinitesimal margin, while the inter-jurisdiction budget allocations are not aligned with the mandate of the sector. The lack of an effective road investment prioritisation model has hindered efforts to address these issues, which have been raised by, amongst others, Ross *et al.* (2002), the Automobile Association SA (2008), COTO (2014), and the National Treasury (2018a).

5.2.1 Discretionary funds

As discussed in Chapter 4, provincial road departments partially fund their road expenditure through provincial equitable share allocations from the national fiscus and provincial own-revenues. Municipal road departments use local government equitable share and municipal own-revenues to partially fund their road expenditure. While the equitable share allocations do account for road infrastructure provision, the fact that the provincial and municipal roads are not a concurrent Schedule 4 function means that the National Treasury and the National Department of Transport (NDOT) cannot ring-fence these funds nor prescribe a minimum allocation. The provinces and municipalities exercise similar discretion over the amount of own-revenues to allocate to road expenditure.

These funding arrangements are associated with key challenges. Firstly, Ross *et al.* (2002) argue that there is reduced pressure on politicians and the voting public to make the correct choices now for society's long-term interests because the benefits of funding roads, and the social damage caused by not funding them, are only noticeable at a point comparatively distant in time from the moment when the funding decision must be made. This challenge is significant given the exponential costs associated with delayed road maintenance, whereby the cost to rehabilitate a road that is left to deteriorate is approximately 18 times the cost of its routine maintenance (SANRAL, 2016). Despite this, provincial and municipal authorities are inclined to shift funds away from road expenditure towards smaller but more immediately recognisable public gains. This pressure is compounded by the problem of the infinitesimal margin, whereby it seems reasonable for authorities to continuously defer the problem of road maintenance by one more year given that one more year of sub-optimal expenditure on an already deteriorated road network does not make a significant difference.

5.2.2 Ring-fenced funds

Provincial road departments also partially fund their expenditure through a combination of the Provincial Road Maintenance Grant (PRMG) and the Expanded Public Works Incentive Grant, while municipal road departments draw on the Municipal Infrastructure Grant, Public Transport Infrastructure and Systems Grant, and EPWP Integrated Grant for municipalities.

Ring-fenced funding in the form of these conditional grants is one way for authorities to avoid the problems identified in Section 5.2.1. But, as exemplified by the PRMG, the allocation of these grants is not strictly determined by economic rationale. The 2018 Division of Revenue Act explains that the PRMG allocations are formulaically determined according to the extent of the provincial paved and gravel road networks, traffic volumes, Visual Condition Index (VC), climatic and topographic factors, and an economic component based on fuel sales (National Treasury, 2018e). The allocations for coal haulage roads and disaster repairs are determined outside of this formula, which is unfortunately not published. While traffic volume and fuel sales are loosely linked with economic activity, the other variables do little to ensure that the grant allocations are matched with any of the road sector mandates.

5.3 EXPENDITURE ALLOCATION

The responses by senior provincial road managers to a survey undertaken by the National Treasury (2018a) indicate serious issues with the road investment prioritisation process. In response to the budget constraints, many provincial road departments have identified roads with the highest total traffic and designated these as strategic routes. These strategic road networks, which invariably comprise surfaced roads, have the first call on limited resources based on the assumption that they have the largest impact on mobility. While this may be true, it is worrying that many departments admitted that minimal consideration was given to basic service access and economic growth as part of the prioritisation process, despite these forming the mandate for the sector. Once the strategic roads have been maintained, leftover funding is apportioned amongst the lower volume roads. Some provincial departments have gone as far as only considering low volume roads for maintenance upon official requests.

In addition to this non-robust selection process for strategic roads, many sub-national road authorities still prioritise their maintenance on a worst-first basis, where roads in the worst condition are assigned a maintenance action and seen to first (SANRAL, 2016). Given that the average cost to repair a road in poor and very poor condition is 6 and 18 times the cost of preventative maintenance on a road in good condition, respectively, this approach risks depleting the available resources on a limited volume of the poorest quality roads with no assurance that these roads are the most important.

The following sub-sections therefore explore the institutionalised, ad hoc, and internationally applied expenditure allocation methods to determine which, if any, are appropriate tools to effectively prioritise road expenditure in line with the mandate assigned to the roads sector.

5.3.1 <u>Institutionalised methods</u>

5.3.1.1 *Benefit-Cost Analysis (BCA) software tools*

The Highway Development and Management Tool (HDM-4) provides a system to analyse road management and investment alternatives. There are several tools that seek to achieve the same outcome, such as dTIMS which is applied by the Western Cape Department of Transport and Public Works and the South African Pavement Design Method (SAPDM) which is being developed by SANRAL. Although there are key distinctions between these tools, they all adopt the same BCA methodology to determine the estimated impact of road investment, prioritise road projects, and optimise budget allocations. In fact, SANRAL uses elements of HDM-4 and dTIMS interchangeably and used the functionality of HDM-4 as the basis to develop SAPDM. While the subsequent discussion is focused on HDM-4 given its widespread use amongst South African road authorities, similar arguments apply to dTIMS and SAPDM.

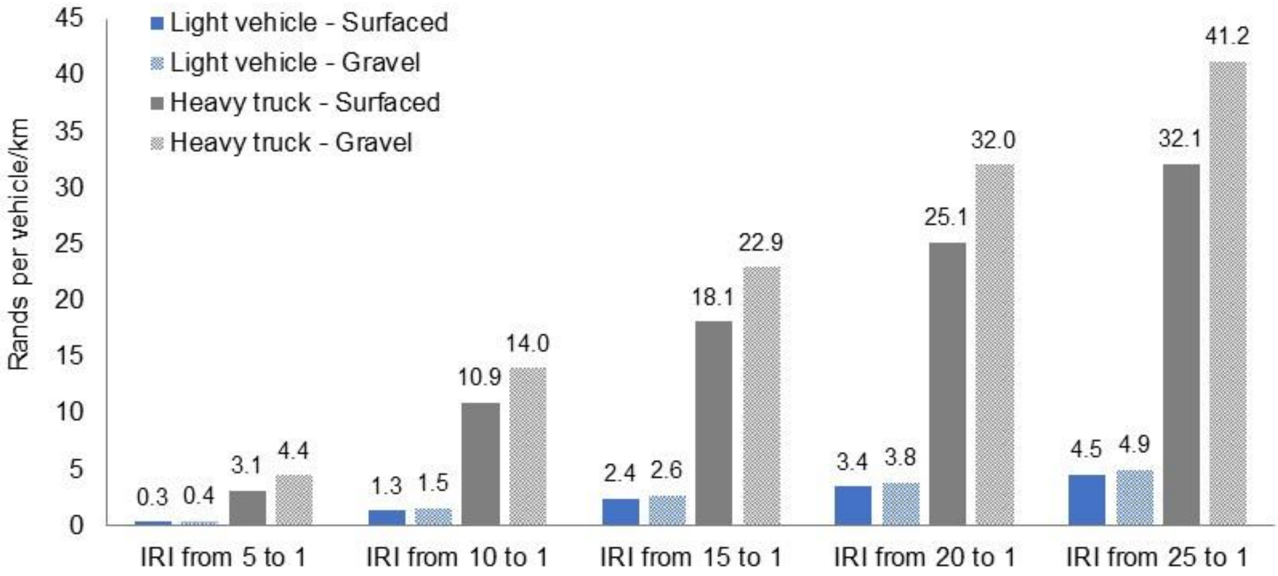
HDM-4 approaches the highway management process in terms of four functions: planning; programming; preparation; and operations (Kerali *et al.*, 2006). Planning analyses the whole road system and generally requires the preparation of medium to long term road expenditure estimates under various budget and economic scenarios. The road system is typically characterised at the planning stage by: characteristics of the vehicle fleet which use the road network; characteristics of the road network, including road class, traffic flows, pavement types, and pavement condition; and the length of road in each category. Programming then applies any budget constraints to prepare tactical multi-year road work and expenditure programmes based on sections of the road network that are likely to require maintenance, improvement or construction. BCA is performed under this function to assess the NPV and internal rate of return of the sets of road works and to prioritise these to best use the available budget. Preparation refines road work designs, generates instructions, a bill of quantities, and costing, and packages the road schemes for implementation. Lastly, operations cover the on-going management and operation of the road department.

The BCA performed by HDM-4 is focused on project costs and the economic benefits to road users in terms of savings in vehicle operating costs, travel time, and accident costs. These road user benefits are respectively calculated for the normal, generated, and diverted traffic components. The World Bank developed the Roads Economic Decision Model in 2003 to account for the external benefits from the provision of road infrastructure, such as better access to social services, but HDM-4 Version 2 added these through an appended “Social and Exogenous Benefits & Costs” tool. This ad hoc external benefit measure in combination with an inbuilt multi-criteria analysis function is intended to widen the application of HDM-4 to lower volume roads and to remove the inherent bias towards roads that carry more traffic.

In the first instance, it is philosophically and legally inappropriate to cost obligations to rights or to trade them off for other outcomes using BCA. A low-volume road that provides access to a primary school, for example, should not be selected for investment based on an estimate assigned to the value of a child’s time or a lump sum “Social and Exogenous Benefit” based on an educated child’s future productivity. Such roads should be prioritised because the South African state is constitutionally obliged to provide access to basic services. It is likely with this, or a similar consideration in mind, that HDM-4 allows the user to earmark specific roads for investment regardless of the tool’s economic analysis. But to invoke this manual prioritisation functionality the user must have prior knowledge about which roads form part of the network that connects communities with basic service facilities.

Secondly, HDM-4 measures the microeconomic user benefits that result from a road project. While this is useful information, the focus on the direct effects of a road project is a potentially misleading measure of the sector’s contribution to economic growth, especially given the NDP’s emphasis on export orientated growth. HDM-4 uses vehicle operating costs (VOC) associated with a given level of road roughness, measured by the International Roughness Index (IRI), to help determine the savings associated with a road maintenance action. Figure 5.1 shows the VOC savings from a variety of road improvement projects. The VOC savings from the road improvements are between 7 and 14 times higher for a heavy truck than a light vehicle. In other words, between 7 and 14 light vehicles must travel on a road to derive the same VOC savings as one truck. But assume there are two identical surfaced roads with flat terrain and an IRI of 10, with the only difference that one of these roads carries 9 light vehicles per day and the other carries only 1 heavy truck. In this simplistic scenario HDM-4 would favour the road carrying 9 light vehicles as this alternative generates a higher VOC saving. But this accounting overlooks the value of the freight transported by the heavy truck. An additional value can be assigned in HDM-4 to the time for freight goods or damage to cargo, but these variables are similarly ill-suited to inform this complicated trade-off. The narrow focus of HDM-4 on road user benefits thus appears misaligned with the mandate to grow South Africa's economy and to prioritise export goods.

Figure 5.1: Savings in vehicle operating costs from an improvement in the IRI



Source: Western Cape Department of Transport and Public Works, 2018a.

Thirdly, South Africa is faced with circumstances that render the first-world utility functions on road construction and maintenance embedded in HDM-4 inappropriate. As Ross *et al.* (2002) argue, the road user parameters tend to favour the construction and maintenance of urban and peri-urban roads over rural alternatives because the former move larger numbers of wealthier and therefore more productive residents. While this appears sensible in first-world countries where governments incentivise rural dwellers to relocate to more productive urban areas or to areas along transport corridors, it is inappropriate in South Africa where the level of infrastructure provision in many urban centres is insufficient to accommodate the high rates of in-migration. Ross *et al.* (2002) contend that under these circumstances a CBA technique that assigns lower weight to the utilities or poor citizens than to those of wealthier citizens is economically inappropriate, politically impractical, and ethically improper.

The sensitivity of the BCA model in HDM-4 to wealth effects requires further interrogation. South Africa combines third-world poverty levels with a sizeable middle class and substantial first-world infrastructure. Because roads derive much of their value from their contribution to the values of other assets that in turn feed wealth-creating productivity, standard BCA tends to favour projects in areas with a pre-existing capital base (Ross *et al.*, 2002). In fact, given South Africa's large GINI coefficient the short-term capital-asset potential of underdeveloped areas is so low relative to the developed areas that BCA will seldom instruct the user to favour projects in underdeveloped areas. HDM-4 does have the functionality to manually input social and exogenous benefits to override the efficiencies measured by the general model, but this renders the original BCA model largely, if not entirely, redundant.

The multi-criteria analysis (MCA) in HDM-4 that is intended to control for predetermined priorities, such as political imperatives, is arbitrary and vulnerable to inconsistent application and manipulation. The MCA tool allows users to assign a weight to the following variables: road user costs; NPV; accident analysis; comfort; congestion; air pollution; energy efficiency; social benefits; and political. But the weightings, which run on a qualitative 9-point scale from "equally preferred" to "extremely preferred", are imprecise and impede efforts to achieve general rationality in resource allocation. Ross *et al.* (2002) also stress that such an approach assigns fundamentally political decisions to technical experts, which places an onerous burden on them.

Lastly, HDM-4 ranks road projects according to their NPV and internal rate of return. This method requires that a base-case be set to form a prioritisation schedule. For example, the financial viability of a road maintenance project is determined according to the road user benefits relative to an alternative action, say no road maintenance, less the project cost. The implication is that road projects, rather than roads, are prioritised and the rank is influenced by various factors including the assumed base-case and existing road conditions. The user could use HDM-4 as a proxy to prioritise roads by selecting either a full maintenance or no maintenance regime as the base-case, however, both options would assign the same road a different ranking depending on whether it was in a good or a deteriorated condition. This is a problem to the extent that some important roads are forced so far down the maintenance schedule that authorities are unable to attend to them within the budget constraint.

HDM-4 is also associated with two less critical issues that can be solved, but until amended negatively affect the tool's accuracy. The market priced cost-saving variables inputted in HDM-4 need to be adjusted as the initial setup is derived from data on least-developed countries. SANRAL performs this task and publishes an annual national level configuration setup. While this approach is practical, Ross and Field (2007) argue that it is unlikely to yield accurate results given the large regional variations in conditions across South Africa. For example, the unemployment rate, which has a significant bearing on the proportion of work-related trips and the value of passenger time savings, was at 27.2% nationally in 2018Q2 but as low as 19.3% in eThekwini Metropolitan Municipality and as high as 35.8% in rural Free State (Statistics South Africa, 2018c). This challenge can be solved through regional configuration and application of HDM-4, but this may be difficult for the incapacitated sub-national road authorities in poorer provinces.

TRH 22 recommends how HDM-4 should account for time savings (Committee of Transport Officials, 2013). Productive time is measured according to per capita GDP divided by the number of work hours in a year, which for 2017 equates to R81.5 per hour. For a network level analysis non-working time is valued at 25.0% of the rate for productive time. These values reflect SANRAL's national configuration setup for HDM-4, except that SANRAL has valued non-work time at 50.0% of the rate for work time. The first issue with this approach is that the country's employment profile is skewed by a bloated and relatively unproductive public sector. In fact, public sector employment accounted for 21.0% of total formal non-agricultural employment in 2017 (National Treasury, 2018b). This should be corrected, along with the inaccuracy introduced by apportioning aggregated output on a per capita basis, by matching the value of work time with labour productivity. Similarly, non-work time should reflect the value of leisure time rather than an arbitrary proportion of the value of work time. These two issues are revisited in Section 9.5.1 as practical constraints to the application of BCA for the road maintenance prioritisation model.

5.3.1.2 *Distributional weights prescribed in TMH 20*

TMH 20 covers the official requirements applicable to the national, provincial, and municipal road authorities for the socio-economic analysis of road projects in South Africa (Committee of Transport Officials, 2017). The prescribed method, which is stated as covering social cost-benefit analysis and social evaluation, specifies the costs and benefits of road projects that must be considered when evaluating the consequences of road investment on welfare.

The socio-economic analysis is project-based and only intended for certain types of road works above a specified minimum threshold value. The project benefits are relative to a null scenario in which no project is undertaken and include any project induced reductions in: road user costs for normal, diverted, and induced traffic (vehicle operating costs; time costs; accident costs; parking costs; traffic reliability; cargo delay and damage costs; and personal security); external costs to non-road users (road barriers reducing cross-road connectivity; availability of transport modes; increased travel distance from urban sprawl; waste disposal; noise; environmental impacts; air pollution; and water pollution); and road infrastructure maintenance costs. Additional economic impacts, such as changes in income and property values, are not included in the socio-economic analysis on the grounds that these are the consequence of savings in road user and non-road user costs and thus already accounted for in the analysis (Committee of Transport Officials, 2017). Projects are then appraised and prioritised within the available budget according to their respective benefit-cost ratios.

When reviewing this approach, which with the exception of non-road user costs mirrors that of HDM-4, TMH 20 raises the same aforementioned issue with the BCA technique, namely: "When a road authority does not have the budget available to implement all economically justified projects and then selects roads based on their economic efficiency, it could happen that projects are selected that will only favour high income groups, which would further aggravate the unequal distribution of income between the different groups" (Committee of Transport Officials, 2017). TMH 20 therefore suggests that an equity-based method using distributional weights should supplement the HDM-4 analysis to prioritise road projects, but only once BCA has proved a project's economic viability.

A distributional weight approach applies different weights to the benefits and costs perceived by different groups of participants in the economy (Jenkins *et al.*, 2013). These weights are usually based on the utility to each relevant group or societal decisions about the importance of incremental purchasing power as it flows to or from groups. The TMH 20 equity-based prioritisation method is premised on the assumption that additional income is relatively more valuable to low-income groups than high-income groups (Committee of Transport Officials, 2017). The economic benefits that fall to lower-income groups from a road project should thus be weighted according to their relatively higher marginal utility of income. By readjusting the road project prioritisation schedule through an inflated weight of the road user benefits accrued to lower-income groups, this method is intended to improve equity between income groups and regions. The welfare distribution weighting assigned to a road and the weight applicable to a specific area can be determined using Equations 5.1 and 5.2, respectively.

$$W_R = \frac{\sum_i P_i}{\sum_i P_i / W_i} \quad (5.1)$$

$$W_i = \frac{C_P}{C_i} \quad \text{For } C_i < C_P, \quad (5.2)$$

$$W_i = 1 \quad \text{otherwise}$$

where W_R is the welfare distribution weight for a road, P_i is the population of area *i* served by the road, W_i is the weight applicable to area *i*, C_p is the average per capita consumer spending of the population, and C_i is the average per capita consumer spending in area *i*.

Despite the noble intentions, the method proposed by TMH 20 faces several objections. The first general objection is raised by Jenkins *et al.* (2013), who note that any actual or implicit transfer of purchasing power from richer to poorer citizens can be thought of as approval of economic waste which would undermine the growth objective. The magnitude of this waste is determined by the size of the differences between the weight of the donor (the rich) and that of the recipient (the poor). Jenkins *et al.* (2013) demonstrate through an example that the application of a distributional externality equates to a willingness to accept a net loss, in efficiency terms, up to the full size of the externality.

The next objection relates to the consistency and implications of using this approach. TMH 20 advises that the equity weights should only be used on roads that are mainly intended to serve low-income areas (Committee of Transport Officials, 2017). The equity weights should either not be applied or a weight of one should be applied to roads that serve a combination of low- and high-income areas. This poses two key challenges: this guideline is imprecisely defined, which essentially leaves the technical expert with a political decision; and for many roads there is not a clear distinction between the different user groups and serviced areas. The following example highlights the potential implications, in terms of the aforementioned economic waste, were authorities to apply this method: assume there are two roads that service the same low-income community, except that the second road also connects a high-income community. Although the second road supports the same number of low-income citizens as well as a higher absolute traffic volume, the method prescribed by TMH 20 would disadvantage it on the prioritisation schedule up until the road user benefits from the high-income users eroded the equity readjustment. This outcome is clearly nonsense, in terms of both equity and economic efficiency.

The third objection refers to the way citizens' right of access to basic services is factored into the analysis. TMH 20 prescribes that the distributional weights are applied following a BCA to determine a project's viability. In addition to the fact that this is an inappropriate way to handle a constitutional obligation, if a project has a large positive or negative NPV using normal economic welfare efficiency prices then distributional weighting the benefits is largely an irrelevant exercise. Distributional weights can make a marginally negative project appear to become marginally positive, but experience shows that marginally positive projects often result in a negative NPV (Jenkins *et al.*, 2013). It is therefore inappropriate and risky public policy to use distributional weights to try to make marginal projects associated with a basic access function appear positive.

Furthermore, the way TMH 20 considers equity is detached from the constitutional obligation on road authorities to address citizens' basic access rights. Regardless of the support this method supposedly affords low-income groups, it does not provide road authorities with an adequate means to consistently identify and justify the provision of low-volume roads that connect isolated communities with basic service centres. It is possible that the prioritisation method prescribed by TMH 20 may still lead to ethically improper outcomes, for example, a road carrying 251 people to the beach on weekends could be prioritised over a road of the same length, servicing the same low-income area, that is the sole route to a primary school with 100 students. Technical experts are thus still required to calculate, and if this estimate isn't large enough then to fabricate, a social and exogenous benefit to input into the relevant BCA model to ensure that lower volume basic access roads are prioritised.

TMH 20 states that, "one of the disadvantages of a weighing system is that it could be subjective and based on value judgements. However, the same applies to the decision not to use a weighting system at all since giving equal weight to all groups is just one weighting system among many, although it does, of course, happen to be the simplest to apply. In cost-benefit analysis the omission of all explicit weighting is associated with allocative efficiency (most efficient allocation of scare resources) and the acceptance of the prevailing income distribution; therefore a decision to apply the economic efficiency criterion is itself a value judgement" (Committee of Transport Officials, 2017). Because the mandate for the sector is to grow the economy, the decision to focus on economic efficiency is not at all an arbitrary value judgment. Nor is it arbitrary to focus on basic access rights as this too forms part of the relevant mandate. What is arbitrary is to introduce a prioritisation method that potentially compromises the mandate to grow the economy whilst not protecting citizens' basic access rights.

5.3.1.3 *Integrated Development Plans*

The Local Government Municipal Systems Act (Act 32 of 2000) requires local governments to prepare Integrated Development Plans (IDPs). The Municipal Financial Management Act (Act 56 of 2003) further requires that the municipal budget be based on the projects included in the IDP. Municipalities thus determine their own infrastructure priorities through their IDPs.

IDPs are intended to promote an integrated, participatory approach whereby all sectors and affected individuals are consulted on investment plans. This consultation is meant to ensure that the needs and concerns of all stakeholders are considered and used to help inform the planning, budgeting, and management decisions in a municipality. The stakeholders include community leaders, donor agencies, citizens, and engineers. Although these stakeholders provide important inputs, Muradzikwa (2004) argues that this makes the process vulnerable to every-day political interference and has introduced community, individual, political, equity, and engineering bias into road prioritisation schedules. While community participation is an important process, a systematic road investment prioritisation model is required to mitigate potential negative effects from rent-seeking behaviour.

The IDP process is grounded in what Hirschman (1960) calls the 'group-focused' image of change, whereby economic progress is conceived as a force that ought to affect equally all members and sections of the community. Where this idea prevails, governments are often unprepared and unwilling to make the choices about priorities and sequences that are the essence of development programs. As a result, municipalities have tended to disperse their budgets across districts, priorities, and disjoint projects to satisfy political demand rather than focusing on the most valuable set of roads (Muradzikwa, 2004).

IDPs are supposed to prioritise road projects, estimate their capital and maintenance costs, and justify their ranking. While some municipalities have managed to achieve and go beyond this objective, many municipalities still lack the requisite planning and budgeting capacities to develop their own IDPs (National Planning Commission, 2012). This is illustrated by high discrepancies in the quality of submitted IDPs. Under-capacitated municipalities often ignore budgetary constraints and rather than effectively prioritising road infrastructure investment they build up unrealistic wish-lists. Muradzikwa (2004) argues that the consultants hired to assist with the IDP process often exploit the ignorance of municipal administrators to compile inferior project lists that are insufficient for effective road prioritisation.

Another major concern with municipal IDPs is that there is no effective system for them to gain the national and provincial support that they require to be meaningful (National Planning Commission, 2012). A standardised road investment prioritisation model is thus required to align the sector departments and local authorities with the same set of national policies.

5.3.2 Alternative methods

Despite the institutionalised prioritisation methods, some road authorities have endeavoured to develop unique road investment prioritisation methods. Although some of the alternative methods consider a relatively wide set of factors, the application is often arbitrary, and they too remain unaligned with mandate assigned to the sector. None of the methods presented below have therefore been recognised for their ability to efficiently prioritise road investment.

5.3.2.1 *Community Access Roads Needs Study*

The KwaZulu-Natal Department of Transport acknowledged in 1997 that the prevailing road prioritisation system overlooked local roads that served rural communities. Although these roads provided communities with access to basic services, this function was ignored by BCA as it lacked market value. To address this oversight and distribute funds more equitably, the department commissioned CARNS Consultants Group (1997) to identify and prioritise roads that would have the greatest effect on rural development. To guide this exercise, CARNS developed the following formula to inform the allocation of funding between districts:

$$\text{District Factor D} = \text{P}\left(\text{a} \times \text{I}_{\text{dp}} + \text{b} \times \text{I}_{\text{cd}} + \text{c} \times \text{I}_{\text{a}}\right) \times 10^{-6} \qquad 5.3$$

where P is population, I_{dp} the Development Potential Index, I_{cd} the Community Development Index, I_a the Accessibility Index, and a, b, and c are weighting constants.

The aim of this formula is to ensure that the road network benefits the maximum number of present and future people. The rationale is that good roads promote development, therefore funds channelled to roads in areas with a higher Development Potential Index should yield better economic returns. The Community Development Index ensures that areas with low growth potential and high populations are not overlooked. Lastly, the Accessibility Index tries to create a balanced road network by giving preference to areas that are poorly served by the existing network. It is, however, problematic that unscientific weightings were assigned such that the Community Development Index contributes a sixth, the Accessibility Index a third, and the Development Potential Index a half to the combined district factor.

Once funding has been allocated, a points-based rating system was also developed to select priority roads within a district (Cronje, 1999). The rating system compares roads according to the probable use that would be made of them by the community, assuming the roads are properly maintained. The following factors were considered by the rating system along with their potential points allocation based on the on the relative value that communities place on a service: population (100); agricultural activities (20); welfare and other administrative services (50); education (40); health (40); business (40); places of worship (10); cultural or historical sites (10); and tourism or recreational facilities (20). The total points are divided by the length of a road to give a rating value per km. Amongst other issues, the scoring system obscures whether a road fulfils a basic access function and how roads contribute to growth relative to one another.

5.3.2.2 *Community Access Road Construction and Maintenance*

The Community Access Road Construction and Maintenance instrument was developed by the KwaZulu-Natal Ministry of Transport (2000). This instrument deviates from the traditional BCA approaches by considering the preferences of local stakeholders, including traditional leaders, rural communities, community leaders, and local business partners. This instrument also seeks to maximise a complex objective function to find the mix of labour-intensive and machine-capital-intensive maintenance strategies that expand employment opportunities. While this is an example of an ethically broad tool, Ross *et al.* (2002) argue that the manner in which outcomes - such as additional jobs that would not be paid for in equilibrium - are assigned to the cost and benefit sides of the ledger violates economic logic.

5.3.2.3 *Roads Agency Limpopo's Capital Appraisal Handbook on Roads*

Klevchuck and Jenkins (2004) developed a handbook for the Roads Agency Limpopo (RAL) to conduct integrated financial, economic, stakeholder, and risk analysis of road projects. The handbook was designed to assist decision-makers with three processes: selecting new roads for construction; allocating funds between road maintenance and road construction; and selecting the roads to be maintained.

This handbook was developed to replace RAL's previous system where road projects were prioritised based on their perceived contribution to the following criteria: current and future traffic volume; population size; existing and potential projects in the agriculture, tourism, mining, and manufacturing sectors; access to schools, hospitals, workplaces, and police stations; and interconnectivity of districts. This mixed set of subjectively assessed factors generated inaccurate prioritisation schedules, as shown by the Department of Finance and Economic Development who assessed 12 roads that were prioritised due to their supposed economic contribution and found that more than half of these roads made relatively low, sometimes even negative, economic contributions and diverted funds from more productive alternatives (Klevchuck and Jenkins, 2004).

Like HDM-4, the handbook's starting point is that the economic value of roads is derived from their function of lowering transportation costs. The benefits of a project capture the reduction in maintenance costs by the road agency, improved vehicle operating costs, time savings of users due to increased average travel speeds, and any possible reduction in the cost of accidents that accrue due to the improved road surface. While this detailed cost-benefit approach is appealing, it is subject to many of the same issues as HDM-4.

5.3.2.4 *Intuitive discretion and Opportunity Value Assessment*

In response to a failed IDP process in the uMkhanyakude District in north-eastern KwaZulu-Natal, the SABITA Infrastructure Development Assessment Project (SIDAP) assisted local authorities to design business plans for clusters of infrastructure projects (Muradzikwa *et al*., 2004). The goal was to select priority projects on a principled basis, to justify these priorities in terms clear enough to release national grant funding, and to prepare business plans that would specify capital costs, future maintenance requirements, and expected generation of further assets from the new road infrastructure.

Muradzikwa *et al*. (2004) explain that rather than a specific prioritisation tool, possible road projects were identified in areas where potential assets were either unexploited or under-exploited due to the absence of road infrastructure. The final project selection was made through a combination of consultation with the stakeholders and basic economic reasoning. Although the resultant road projects proved a success, it is not clear that most contractors could use economic reasoning to such good effect. It is also not financially viable for the authorities to continuously hire highly skilled consultants. SIDAP thus aimed to develop an Opportunity Value Assessment instrument to complement stakeholder surveys with rigorous and quantitative assessment. This instrument was never developed, but nevertheless would still need to be supplemented with some method to prioritise citizens' basic access rights.

5.3.2.5 *Rural Road Operation Plan*

The Mbonambi Municipality (2010) in KwaZulu-Natal undertook to identify the community access roads that, based on apparent need and benefit, should be proclaimed as part of the municipal network, and then to establish a strategy to prioritise the municipality's order of works. The degree of benefit provided by a road was determined according to the number of connected homesteads, with additional data used to inform the prioritisation: topography; prevailing soil types; number of community facilities served; and road width, condition, and length. A subjective cut-off point was applied to the number of connected households to determine which roads were sufficiently important to justify maintenance. But this approach ignores the economic activity supported by a road and potentially violates the basic access rights of citizens served by roads that connect less than the threshold number of households.

5.3.2.6 *KwaZulu-Natal Department of Transport's Project Prioritisation System*

Royal HaskoningDHV (2014) developed a Project Prioritisation System for the KwaZulu-Natal Department of Transport to facilitate the ranking of all road network projects within the province based on technical criteria. The purpose was to prioritise national, provincial, and municipal road infrastructure within the province and to provide schedules to assist with: comparisons between alternative road segments within the network; preparation of project programmes; and determination of transport network needs and backlogs.

This system assigns each road points based on the following factors: road classification; strategic and primary road network; traffic volumes; public transport routes; tourism routes; development nodes; commercial areas; agricultural potential; priority intervention areas;

social facilities; and population served (Royal HaskoningDHV, 2014). Roads that score relatively more points are then prioritised over roads that score fewer points. Although the factors used to assess the roads appear quite comprehensive, the scoring relies heavily on previous classification exercises and the points system is arbitrarily determined. The system does not accurately reflect either of the networks' core mandates, for example: a gravel road with projected AADT between 500 and 999 vehicles scores 60 points and is prioritised over a surfaced road carrying more than 30 000 vehicles which scores only 50 points; and a road which has 5 public transport operators scores 40 points and is prioritised over roads that are connected to all schools (high schools score 30 points and junior schools 20 points) and hospitals (regional hospitals score 30 points, local hospitals 20 points, and clinics 15 points). In fact, the system only considers a road as connected to a social service facility if it is within 500 m of the nearest facility regardless of that road's position along an access route. Within this context, it problematic that the system recommends that roads connected to less than 10 households should be left as tracks as this potentially violates the basic access rights of isolated communities. The system therefore neglects the Department's constitutional duties and potentially misrepresents the economic contribution made by each road.

5.3.2.7 *Regional economic impact analysis*

Since 2012, SANRAL has recommended the use of regional economic impact analysis in the economic evaluation of road projects (Pienaar, 2016). This method uses regional income multipliers to estimate the once-off increase in regional income during road works, and the recurring increases in regional income during road use. This method also accounts for the road user and non-road user benefits (general regional economic benefits) provided by a road project. The road user benefits consist of vehicle operating, accident, and time costs. Pienaar (2016) uses Equation 5.4 to estimate the present worth of the expected additional regional disposable income from accelerated economic activity during the road's service life:

$$EA_0 = \sum_{t=k}^{n} \frac{EA_t \times (A-1)}{(1+i)^t} \qquad 5.4$$

where EA_0 is the present worth of the additional regional income arising from accelerated economic activity during the service period of the road, EA_t is the total road user benefits of the facility in year t minus the value of travel time savings during non-working time and the value assigned to lives saved, *A* is the gross regional income accelerator, *i* is the annual discount rate expressed as a decimal fraction, *k* is the first year of operation, *n* is the number of years in the analysis period, and *t* is any particular year in the analysis period.

In terms of non-road user benefits, Pienaar (2016) explains that a portion of the construction expenditure for a road goes to business and consumers through remuneration of employees for services and goods rendered on the road project. Consumers are inclined to save some of the post-tax income and to spend the remainder. Depending on the propensity to import project inputs from outside the region, the investment expenditure on the road increases the disposable income of the regional population. The repetitive nature of the process multiplies the income-creation effect of the road construction expenditure (Pienaar, 2016).

Because road user benefits are quantified using a similar BCA technique as HDM-4, except that the total benefits are multiplied by the gross regional income accelerator *A*, the relevant arguments presented in Section 5.3.1.1 also apply to this prioritisation method. Moreover, while it is mentioned that road projects allow government to spatially distribute basic service centres more equitably, the basic access function is not considered in the model.

5.3.2.8 *Western Cape Department of Transport's economic model*

De Vos *et al*. (2017) note that the two objective functions, Area-under-the-Condition Curve (AUC) and Total Transport Cost (TTC), used by the Western Cape Department of Transport for network optimisation in dTIMS are both limited with respect to incorporation of economic growth and equity. The AUC objective function estimates the incremental benefit relative to cost for alternative intervention strategies for a road segment. The benefit of an intervention strategy for a road segment (*Benefit*) is calculated in Equation 5.5 by summing the present value of the difference between the condition index resulting from the intervention strategy (IS_Cond_i) and the condition index from the do-nothing alternative (DN_Cond_i), weighted by the annual average daily traffic ($AADT_i$) and for each year in the analysis period (*i*) (de Vos *et al.*, 2017). Strategies that improve the condition of a road segment will result in a positive area above the curve of the do-nothing alternative. The incremental benefit of alternative intervention strategies relative to cost are then compared in the optimisation analysis.

$$Benefit = \sum_{i=1}^{Total\ years} AADT_i(IS\_Cond_i - DN\_Cond_i) \quad 5.5$$

While the AUC function considers economic benefits relative to costs incurred for alternative intervention strategies per road section, it is criticised by de Vos *et al.* (2017) for ignoring the broader economic context of where a road segment is located relative to other competing road segments. To account for this oversight, de Vos *et al*. (2017) augment the weighting parameter of the AUC objective function in Equation 5.5 by adding economic activity at the local municipality level. The augmented objective function is presented in Equation 5.6.

$$Benefit = \sum\nolimits_{\forall,j,i} \{\left(\frac{AADT_j \times km_j}{\sum_{\forall,j} AADT_j \times km_j}\right) Econ_i\}(IS_{Cond} - DN_{Cond}) \quad 5.6$$

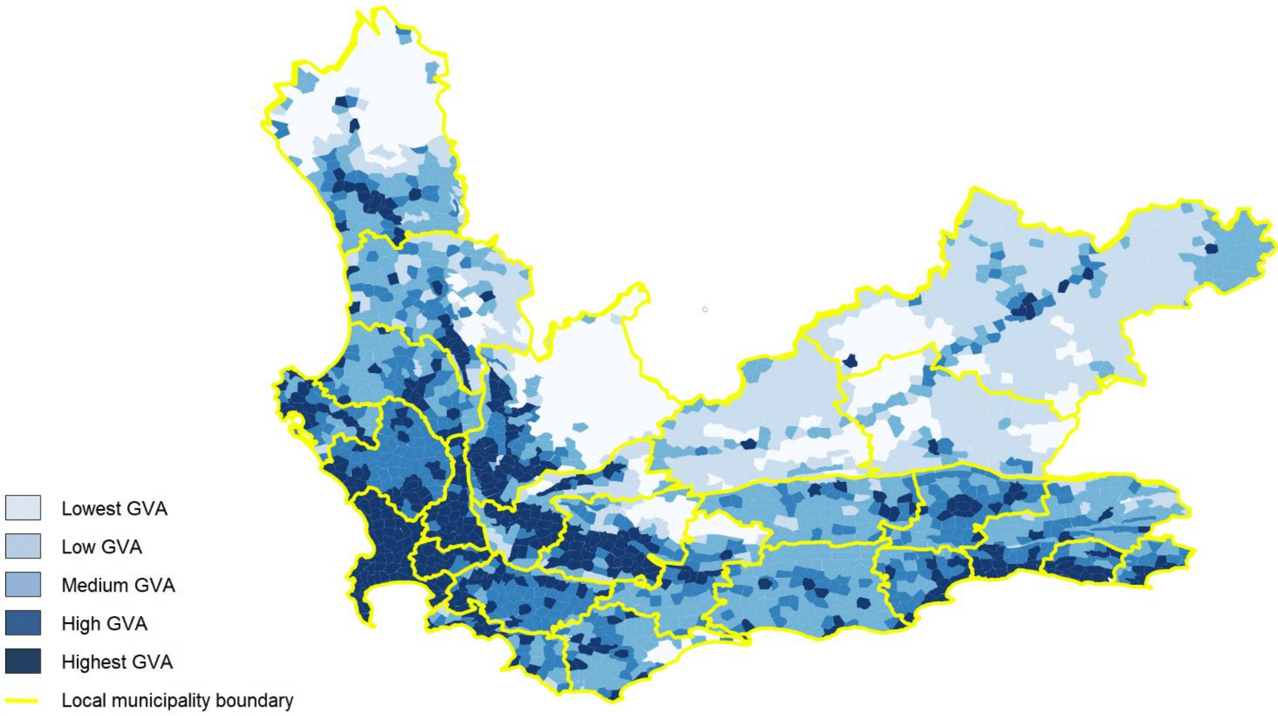
where *Benefit* is the benefit of an intervention strategy for a road segment, $AADT_j$ is annual average daily traffic on road segment *j*, km_j is the length of road segment *j*, $Econ_i$ is the size of the economy in sub-area *j*, *j* is the road segment, *i* is the sub-area in the evaluation area, IS_{Cond} is the condition of the road segment for the intervention strategy, and DN_{Cond} is the condition of the road segment for the do-nothing strategy.

De Vos *et al.* (2017) argue that the inclusion of vehicle-kilometres into the objective function enables competition between road links with different lengths and traffic volumes. While the introduction of the economic weight of different sub-areas that constitute the area under considerations is intended to reflect the underlying distribution of economic activity. These augmented objective function weighting parameters result in the re-ranking of road links.

De Vos *et al*. (2017) draw the preliminary conclusion that this approach allows for a more economically equitable allocation of resources in network management. There are, however, some methodological shortfalls to this approach. In addition to overlooking the basic access function of a road, trucks and passenger vehicles are assumed to carry equivalent economic weight in the $AADT_j$ parameter. Different vehicle classes contribute differently to output, with passenger vehicles primarily transporting people and trucks primarily transporting freight. The objective function should disaggregate the vehicle classes to account for this distinction.

From a network perspective the augmented objective function risks mis-prioritising trade routes that cross multiple local municipalities. Figure 5.2 illustrates the distribution of Gross Value Added (GVA) in 2010 in the Western Cape Province (CSIR, 2018). The augmented objective function obscures the fact that output is transferred from places of production to consumption, which may require transport across areas with a different level of GVA. To the extent that $Econ_i$ distorts the AADT weighting parameter, Equation 5.6 would assign road links transporting the same vehicles and goods varying priorities depending on the level of GVA in the surrounding area. The implication is that this creates potential inefficiencies and discrepancies in service along trade routes.

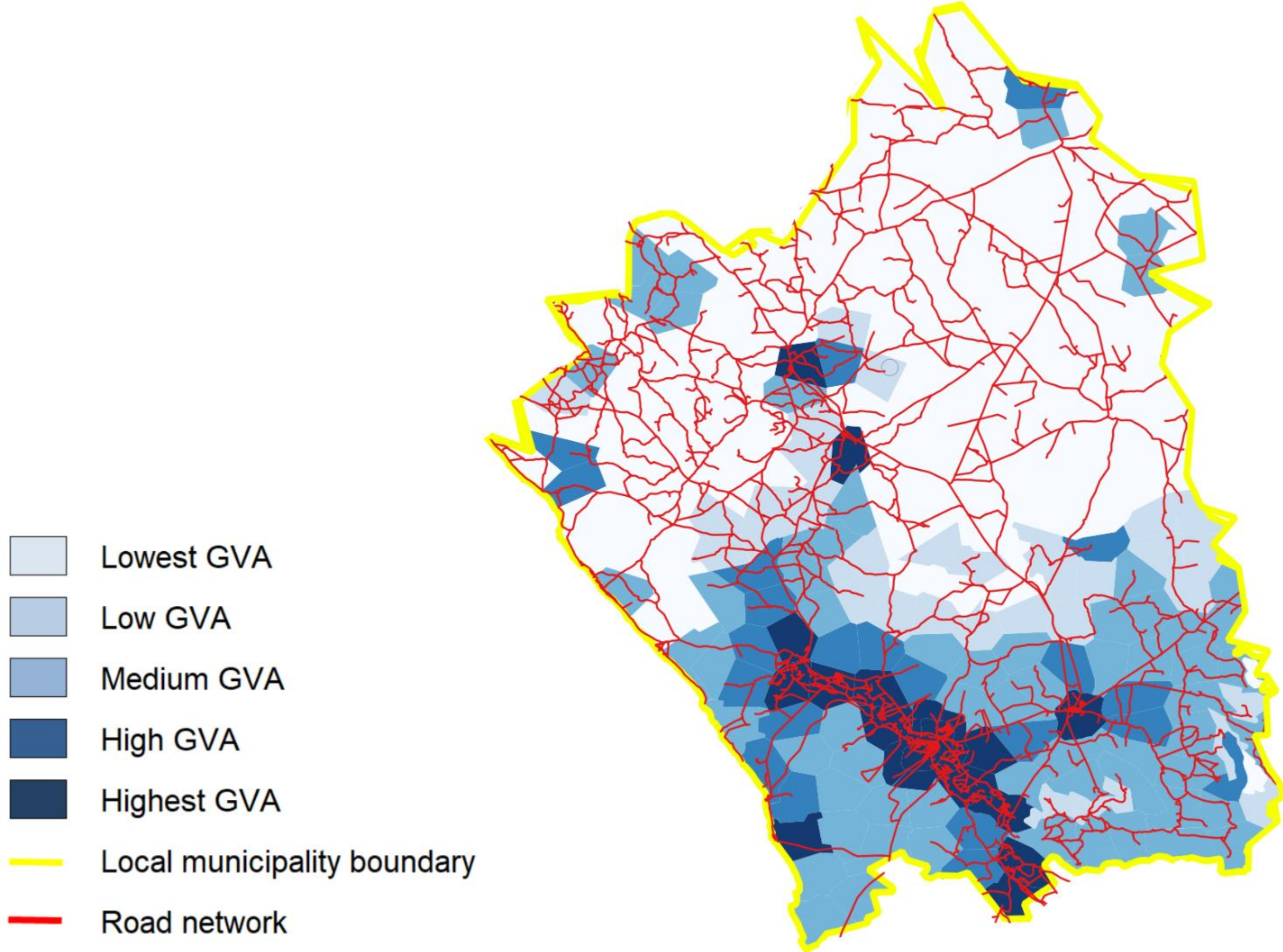
Figure 5.2: Gross Value Added within local municipalities in the Western Cape



Source: CSIR, 2018a.

The inaccuracies introduced by this augmented objective function are demonstrated through Figure 5.3, which shows the variation in GVA within the Matzikama Local Municipality in the Western Cape Province. Despite the extreme variation in GVA, with all 5 of the national GVA categories represented in Matzikama, Equation 5.6 assigns the same $Econ_i$ weighting (size of the economy) to all of the roads within this sub-area. While the $AADT_j$ parameter will help to distinguish between roads within the local municipality, assigning all roads within a local municipality the same $Econ_i$ weighting potentially lowers the network level ranking of roads associated with relatively higher output than the municipal average and similarly inflates the network level ranking of roads associated with lower output than the municipal average.

Figure 5.3: Variation in Gross Value Added within the Matzikama Local Municipality



Source: CSIR, 2018a.

5.3.3 Other international methods

5.3.3.1 *Rural accessibility index*

The World Bank developed a rural accessibility index (RAI), defined as the proportion of the rural population who live within 2.0 km of an all-season road, to prioritise road investments based on their impact on rural access and connectivity (Mikou *et al*., 2019). The only roads considered all-season and serviceable are paved roads in good or fair condition and gravel roads in good condition. On this basis South Africa was assigned a RAI of 77.0. However, the authors acknowledge that because WorldPop uses roads as a factor to model population distribution the analysis is subject to endogeneity which could lead to an overestimation of rural accessibility. Yet no remedial action was taken to remedy this endogeneity concern.

Moreover, the RAI is only focused on accessibility to a road, which is not necessarily aligned with the specific prioritisation objectives of South African road authorities. For instance, the RAI does not consider the services connected to a road or the proximity of a rural population to basic service centres. While prioritising roads in close proximity to the highest number of isolated rural communities might improve access to basic services or stimulate economic growth, this criterion is insufficient to guarantee either outcome.

The methodology applied by Mikou *et al*. (2019) also held the road network fixed. However, what is required in South Africa is a methodology to optimise the road network by identifying redundant roads within the network that authorities can unproclaim. This is goal is especially important given the relatively high density of the South African road network, the significant road maintenance backlogs, and the fiscal constraints.

5.3.3.2 *Condition Index and Priority Factors*

Road authorities, such as the Tanzanian Ministry of Works, Transport, and Communication (2016), also prioritise their road networks using similar multi-criteria analysis methods to the Western Cape Department of Transport's economic model presented in Section 5.3.2.8. The iteration presented in Equation 5.7 was forwarded as an option to prioritise investments in rural roads in Tanzania according to the current condition of each road link and its economic and social importance:

$$Priority\ score = CI_i \times \alpha T_i \times \beta A_i \times \delta S_i \times \theta P_i \qquad 5.7$$

Where CI_i is the Condition Index of road *i*, T_i is the volume of traffic on road *i*, A_i is the agricultural output of the area served by road *i*, S_i is the existing social facilities along road *i*, and P_i is the population served by road *i*. α, β, δ, and θ are weightings applied to each factor depending on its relative importance. CI is higher for roads in poorer condition. This approach is therefore intended to prioritise interventions on roads that are in a deteriorated condition but serve a relatively high combination of social and economic functions.

But δS_i would have to be assigned to all roads that form the most effective access route between households and the closest basic service facilities, not just the roads with a basic service facility along them, to ensure that authorities efficiently maintain all roads required to protect citizens' basic access rights. δS_i must also negate the other factors otherwise, to the extent that *T*, *A*, and *P* distort the priority score, roads located in areas with relatively low agricultural output that serve a low population might be overlooked for maintenance given constrained budgets despite citizens' reliance on them to access basic service facilities.

In addition to potentially violating citizens' basic access rights, Equation 5.7 is an inaccurate method to determine which roads and combinations of roads make the highest contribution to economic growth. Similar to the arguments raised in Section 5.3.2.8, this approach risks disrupting service along trade routes if road links on the same route are assigned different priority scores based on potentially irrelevant factors within their respective regions.

The population serviced by a road, θP_i, introduces an unnecessary noise variable into the prioritisation process. This population variable is intended as a proxy for road user demand, but this characteristic is already and more accurately captured through road traffic, αT_i. The fact that a road services a relatively larger population should not artificially inflate its ranking, otherwise the prioritisation process may unduly bias existing spatial patterns and potential road user demand over actual road user demand.

In terms of prioritising roads that make the highest contribution to growth, the single focus on agricultural output excludes other productive activities, such as mining, from the analysis. While this criticism could be resolved by augmenting Equation 5.7 to capture all economic activities, as argued in Section 5.3.2.8 regional output remains an imperfect measure of the contribution made by specific roads. Sections 5.3.1 and 5.3.2 also argued against using a disaggregated road traffic variable, such as αT_i, to measure a road's economic contribution.

5.3.3.3 *ISABELA*

The Conference of European Directors of Roads (CEDR) (2016) integrated social aspects and benefits into life-cycle asset management. This project, referred to as ISABELA, aimed to identify clear and repeatable social key performance indicators to include monetary and non-monetary social effects, social backlog, and social risk at a network level in classical asset management programs.

The indicators were gathered through a combination of literature reviews and interviews with interested road authorities. The aim was to identify which indicators were used, and which additional indicators there was interest in using, in asset management programs. The final indicators were grouped into four areas: availability and disturbance (accessibility, condition, congestion, restrictions, travel time, and user satisfaction); road safety (accidents, condition, overall safety, safety costs, and users' perception); environment (air quality, CO_2 emission, natural resources, noise, and soil and water quality); and socio-economic impact (asset value, condition, cost efficiency, environmental costs, safety costs, users' costs, wider socio-economic costs, and stakeholder satisfaction) (CEDR, 2016).

The indicators introduce some important parameters to help authorities satisfy citizens' basic access rights, for example "road availability" covers the importance of a road connection and the possibility of using alternatives. But because none of the chosen indicators address the service centres connected to a road, the usefulness of this system for South African road authorities is unfortunately limited. Again, economic activity is only measured by road user costs and the same traditional BCA technique critiqued above was applied.

5.3.3.4 *Integrated Rural Accessibility Planning*

The Integrated Rural Accessibility Planning (IRAP) tool was developed by the International Labour Organisation (ILO) (2003) to enable local level planners to prioritise rural investment projects to improve the accessibility of basic service facilities to rural communities. The IRAP tool has been used by, amongst other countries, Ethiopia, Malawi, Zimbabwe, and Uganda.

The ILO (2003) states that the main objective of access interventions is to reduce the time, cost, and effort for rural communities to gain access to basic services, most commonly water, fuel, health, and education. The IRAP approach thus aims to integrate rural communities' mobility needs, the location of service facilities, and the provision of appropriate transport infrastructure into the project prioritisation process. Based on the method prescribed by the Tanzanian Ministry of Works, Transport and Communication (2016), Equation 5.8 estimates the difficulty with which rural communities' access various facilities:

$$AI = N(T - T_m)F \qquad 5.8$$

where *AI* is the Accessibility Indicator, *N* is the number of affected rural households, *T* is the average travel time to a facility, T_m is the target travel time, and *F* is the frequency of travel. Projects are ranked in descending order of the Accessibility Indicators, which is intended to prioritise projects that most effectively reduce aggregate travel time and effort.

While the IRAP tool may improve accessibility to basic services for many rural citizens, the tool is not specified to ensure that all rural roads that provide citizens with their only viable means to access basic service facilities, regardless of the number of people affected, are prioritised. Irrespective of whether a community wholly relies on a specific road to access basic service facilities, to the extent that travel time (*T*) matches the prescribed norms and standards (T_m), the IRAP tool will rank specific roads lower if they connect a relatively small number of citizens to basic service facilities.

The frequency of travel variable, *F,* serves to assign different priority scores to roads that connect communities to different basic service facilities. Although access to basic education and healthcare facilities are both constitutional rights in South Africa, Road A with identical characteristics to Road B would be assigned a lower priority score if it was connected to a healthcare facility and Road B was connected to basic education facility due to the relatively intermittent demand for healthcare services.

Although the IRAP tool was not primarily designed to prioritise roads that make the highest contribution to economic output, one of the stated applications of the tool is to prioritise roads that facilitate household access to markets. In this case the *AI* estimate assumes that the number of households and the frequency of travel correlate with transport demand, which in turn represents the value of marketable goods transported by road. But neither assumption is necessarily true.

5.3.3.5 ***Freight-based prioritisation framework***

Schroeder *et al.* (2012) developed a framework for prioritising infrastructure improvements on critical freight corridors in the United States. Like South Africa, the project was motivated by the need to ensure that limited funds were efficiently distributed within the ageing road network to important freight routes. Their freight-based prioritisation framework can be used alongside existing asset management systems and applies an input-output model to identify the most transportation dependent industrial sectors, which are then linked with commodity flows using the Federal Highway Administration's Freight Analysis Framework to identify the relative economic importance of highway links. An inoperability input-output model estimates the productivity losses from excess trucking costs due to a change in service on a road link. While this prioritisation framework is inappropriate for providing access to basic services, it is appealing from an economic growth perspective and hence revisited in Chapter 9.

5.4 CONCLUSION

The critiques of the available prioritisation methods are in line with World Bank frameworks, which stress the importance of capturing the economy-wide impacts of projects (Andres *et al.*, 2015). The methodological framework put forward by the World Bank divides economy-wide impacts into two categories, economic growth and distribution impacts, which reflect the mandate assigned to the South African road sector. No prioritisation model was able to satisfy both mandates. Interestingly, even the models with a singular focus on basic access or economic growth were inefficient when judged against the country specific requirements.

In line with the criticisms presented in RIFSA and the Rural Road Strategy, the prioritisation methods continue to neglect the distributional impact of the sector in the form of access provision to basic services. An effective road investment prioritisation model must not lose track of the country's social goals nor misinterpret basic access rights as an objective that can be traded off for economic growth. Unfortunately, the traditional BCA techniques applied by systems such as HDM-4 are designed to address the first-world economy context and are only able to build in arbitrary conceptions of social priorities. If these BCA methods were applied as the only decision tool by South African authorities, the resultant road investment prioritisation schedule would likely be economically inappropriate, politically impractical, and ethically improper. However, there remain many alternative applications for which road asset management systems such as HDM-4, dTIMS, and SAPDM can and should be used.

The road investment prioritisation model must conceptualise how the road sector achieves its second mandate, to support economic growth. The basis for resource allocation decisions must be general economic rationality, bearing in mind the criticisms that regional activity and traffic volumes do not necessarily equate to the economic value of a road. In this regard, it is important that the prioritisation model reflect the national priority to increase economic growth through export promotion. Perhaps the biggest challenge identified by this review is to develop a road prioritisation model that supports established patterns of economic activity whilst remaining sensitive to wealth effects and the opportunity value in un-exploited and under-exploited areas. These points are discussed further in Chapter 9.

The road investment prioritisation model also needs to be implementable at a network level to respond to the NDP's call for a system that resolves poorly coordinated intergovernmental planning, disconnects across municipal boundaries, and the divide between how authorities manage economic growth (National Planning Commission, 2012). National level application is also an effective means to: inform the distribution of revenue allocations from the national fiscus; guide provincial and municipal budgeting decisions; and ensure that incapacitated sub-national road authorities are accommodated in the prioritisation exercise, which to-date has been a serious challenge as witnessed by the significant deterioration in network quality and the obvious neglect of core roads (National Department of Transport, 2006). Linked to this is need for the prioritisation model to remove any burden on technical experts to make political decisions, and similarly for external political inputs to influence technical experts.

Significant levels of investment prioritisation are already happening within the provincial and municipal road networks given the extent of the budget constraints. But the provincial road departments, which have more capacity than many of the municipal road departments, have been cited for and admit to applying a variety of inappropriate prioritisation methods. Without a consistent method to guide road investment prioritisation there is an extremely high risk that the limited resources available to the sector are neglecting citizens' basic access rights and delivering sub-optimal economic growth outcomes. It is therefore essential to develop a road investment prioritisation model that can simultaneously protect basic access rights and support economic growth, without unduly favouring either of these important objectives.

6 A COST-EFFECTIVENESS ANALYSIS-BASED ROAD CLASSIFICATION SYSTEM

Chapter 5 identified the urgent need for a network level road investment prioritisation model for South Africa that reflects the policy priorities set for the roads sector to satisfy citizens' constitutional right to access basic services and to maximise potential economic growth. The first step in the development of this road investment prioritisation model is to ensure that roads are classified according to whether they provide a basic access or economic growth function, or a combination of these functions. The cost-effectiveness analysis-based (CEA-based) road classification system developed in this chapter therefore moves away from the focus of current road classification systems on factors such as road traffic, design, function, and ownership to account for the type and relative value of the economic service provided by a road. This innovative road classification system separates the network into tiers that represent lexicographical priorities based on the network mandate. This information enables authorities to plan their maintenance schedules in descending order of importance and to focus on cost-effectively satisfying the maintenance demands within each tier to maximise the funding available for subsequent tiers.

Section 6.1 provides a critique of the current road classification systems. Each classification system is assessed in relation to the mandate of the sector to address citizens' basic rights and grow the economy. Because the available road classification systems are intended for purposes other than identifying the economic service of a road, none of these systems are either individually or cumulatively sufficient to support economic prioritisation of the network. Without the necessary road classification system authorities risk potentially inaccurate road prioritisation, which in the context of limited budgets implies inefficient public expenditure.

Given this gap in the current road classification systems, Section 6.2 covers the fundamental criteria for an effective road classification system. The CEA-based road classification system developed in this chapter adheres to the following three principles in order to be acceptable to the South Africa road authorities: a manageable set of practically relevant road classes; unambiguous descriptive terminology to define each road class; and road classes that are scaleless and ubiquitous across the network.

Section 6.3 presents the CEA-based road classification system, which comprises four road classes: Basic Access Roads; Strategic Roads; Tactical Roads; and Surplus Roads. The prioritisation rule applied to these road classes prioritises Basic Access Roads over the road classes that support economic growth, namely Strategic and Tactical Roads, as both philosophical and economic arguments, which are consistent with a neutral reading of the South African Constitution, prioritise the welfare of the least well-off citizens. Having defined a robust prioritisation rule, each road class is individually explored with attention given to the definition, identification methodology, and potential extent of the network.

Section 6.4 concludes with the inclusion of this CEA-based road classification system within the Road Asset Management Systems (RAMS) as well as the important findings from this chapter. The two main findings are that much of the demand for access to basic services can be satisfied by roads that fulfil both a basic access and economic growth function, and that road authorities can maintain the Basic Access Road Network within the current budget parameters and still have significant budget for the maintenance of growth-promoting roads. These findings indicate that the development of the road maintenance prioritisation model, which occurs in Chapter 9, can proceed with certainty about its application.

6.1 CRITIQUE OF THE CURRENT ROAD CLASSIFICATION SYSTEMS

Road classification systems classify roads according to given roles and then order the road classes in relation to one another to help authorities better administer, finance, and manage their road networks. The National Department of Transport (NDOT) (2006) emphasise that road classification cannot be considered from a one-dimensional perspective that fails to account for the socio-political and economic imperatives of the country. As discussed in Chapter 5, South African authorities must ensure the limited road maintenance resources are allocated such that road maintenance schedules protect citizens' constitutional right to access basic services and maximise potential economic growth. However, none of the available road classification systems, which are introduced below, reflect either of these two objectives. This mismatch between the purpose of the current road classification systems and the objectives to support basic access and economic growth mean that authorities lack the necessary information to inform an economic prioritisation of the road network.

6.1.1 Legal definitions

Proclaimed roads are designated as either National, Trunk, Main, Divisional, or Minor roads. These legal definitions are in term of the National Road Act and Road Ordinance, Ordinance 19 of 1976 (Provincial Administration Western Cape, 2002). These legal definitions are used to determine responsibility, with the National and Trunks roads managed by SANRAL and provincial road authorities, respectively, and District Municipalities managing the remaining road designations. The definitions for the road designations are based on the statutory road reserve width and road location, with no attention given to the road service.

6.1.2 Naming hierarchy

The naming hierarchy system classifies roads according to their names. Numbered mobility roads are the first class and include freeways, bypasses, motorways, expressways, routes, highways, and arterials. The next class are numbered and named mobility roads and include avenues, roads, drives, and links. The lowest class are access and activities streets which include boulevards, collectors, streets, lanes, loops, crescents, places, ways, courts, groves, terraces, squares, and malls. This classification system is intended for public information to help manage users' expectations. However, in terms of economic prioritisation the classes provide no detail about connected service centres and economic activity.

6.1.3 Road Traffic Signs Manual Classification

This system classifies roads according to four classes: Class A1 dual carriageway freeways; Class A2 single carriageway freeways; Class B1 non-freeway numbered national, provincial, regional and metropolitan routes; Class B2 un-numbered surfaced routes; Class C1 low-volume surfaced routes, local collector-distributor streets; Class C2 un-numbered gravel and industrial streets; and Class D local access roads with no public destination. These classes are based on road design and, to a lesser extent, traffic volumes and therefore bear no direct relation to basic service access or economic activity.

6.1.4 Route number classification

The route numbering classification system expresses ownership, with the prefixes N, R, and M for national, provincial, and municipal roads, respectively. Provinces further differentiate their roads by using D for district roads, T for tourist routes, and respectively adding two- and three-digit numbers to major and minor R routes (COTO, 2012). While route numbers help guide motorists, they are inadequate for economic prioritisation as the definitions are unrelated to the service provided by a road.

6.1.5 Administrative classification

Administrative classification categorises roads according to the responsible authority, either national, provincial, or local government. Each authority is accountable for management of their designated road network. There is, however, no standard methodology to determine the assignment of roads. Current legislation defines national, provincial, and municipal roads as those proclaimed as such with no set rules to govern the process (COTO, 2012). The NDOT (2006) argue that the administrative classification system has proved insufficient to coordinate overlap of services between roads assigned to different authorities. The origins and destinations of many economic activities are on sub-national roads, making them part of strategic supply routes. But this system only classifies national roads as strategic assets. The NDOT therefore called for a new classification system that can identify strategic roads at all levels of administrative classification.

6.1.6 Geometric classification

Geometric classification draws on the structural determinants of a road such as road width, surface type, wet weather condition, gradient, load bearing, and height restrictions to class roads according to their design (Intergovernmental Committee on Surveying and Mapping, 2006). For example, Freeways are in a higher class than dual carriageways, which in turn are above undivided arterials. Changes to the structural determinants and geometric design along a road mean that segments of the same road can be classified differently. The system is used in South Africa to aid design processes and communication between engineers and administrators. No direct relationship, however, can be drawn between geometric road types and either a road's basic access or economic growth function. In fact, the NDOT (2006) note that undivided, two-lane roads can contribute more to road freight and passenger mobility than geometrically superior dual-carriageway multi-lane collectors. The OECD (2001) also reject the appropriateness of this engineering-based road classification system to plan road networks according to economic considerations.

6.1.7 Functional classification

The NDOT developed South Africa's functional road classification system in the early 2000s to inform land use and transportation planning across the spheres of government (Provincial Administration Western Cape, 2002). This system classifies roads according to their service within a network, which is determined by the degree of traffic mobility and land access they provide. Mobility roads are higher speed through-routes linking centres of economic activity, and thus have limited access points as this slows traffic. Access roads are shorter in distance and cater for access to land, activities, and services. The proportion of mobility and access provided by a road determines its class, with higher mobility and access mutually exclusive.

Three criteria are used in TRH 26, which is the functional classification manual, to distinguish between the six functional road classes (COTO, 2012). The size and strategic value of the trip generator is the first criterion. According to TRH 26, mobility roads link large or important trip generators and rural and urban centres of development. Access roads give direct or indirect access to properties and collect and distribute traffic between those properties and mobility roads. The next criterion is the reach and connectivity of a road. While mobility roads cater for longer travel distances, access roads only facilitate shorter trips. To avoid speeding in urban areas, access roads should not exceed 1 km before connecting with a mobility road. Lastly, the travel stage is considered. Trips are undertaken in three stages: local at the origin, through when away from the origin or destination, and local at the destination. TRH 26 states that the local portions of a trip should be on access roads, while the through portion should be on mobility roads.

The NDOT (2006) conclude the Road Infrastructure Strategic Framework for South Africa by stressing the need to develop a framework to support economic growth sectors through the provision of road infrastructure. One of the reasons functional classification fails to fulfil this demand is its imprecise relation to economic value. Although high order mobility roads usually facilitate more economic activity than lower order mobility and access roads, this is not always true as the classification hierarchy is movement based. For example, the NDOT (2006) identify that more economic value can be supported by low order mobility and access roads connected to key service centres or in densely populated areas than by higher order mobility roads for through travel in areas with low levels of production.

Functional classification also lacks the requisite detail to identify which facilities are serviced by a road. This makes it impossible to systematically identify the roads connected to basic services essential to some specific population. It is erroneous to treat all Class 5 roads as equivalent or to prioritise all Class 4 roads before Class 5 roads, as each road provides a unique service that will affect the prioritisation exercise. The NDOT (2004) therefore admit the functional classification system was “not intended to suggest how priorities and funding allocations should be made”.

6.2 FUNDAMENTAL CLASSIFICATION CRITERIA

The fundamental criteria for an effective road classification are covered in a seminal report on road classification developments by the Intergovernmental Committee on Surveying and Mapping (ICSM) (2006). The CEA-based road classification system must comply with these criteria for the system to fulfil the minimum requirements for acceptance by the South African road authorities.

The first criterion is a small number of road classes. The ICSM note the need for trade-offs between simplicity and accommodation of all road classes. But while officials should be able to effectively manage and work with the classification system, no practically relevant road classes can be excluded when rationalising the theoretically possible classes.

The second criterion is that classification systems use unambiguous descriptive terminology for the road classes. The definitions should be distinct, clear, and concise to ensure simple and objective application of the classification system. Broad definitions of classes allow more scope for interpretation and thus impair consistent application of a classification system.

The third criterion is that road classes are scaleless and ubiquitous across the network. The entire road network must be consistently classified rather than sections in isolation from one another. Because modifications to classes that account for regional significance detract from the countrywide effectiveness of a classification system, all distinguishing variables must be applicable across the whole spectrum of roads.

The final criterion is hierarchical contiguity, which requires that the roads in the same class connect to form a continuous network. The rationale is that network integrity is improved if authorities are responsible for the maintenance of seamless road networks. However, this criterion undermines efficiencies obtainable from prioritising across the South African road network as a whole. It could enjoin maintaining or upgrading a tactical road A because it connects tactical roads B and C, even in a case where B and C are relatively efficiently connected by a strategic road D. Therefore the CEA-based road classification system does not aim to satisfy this criterion.

6.3 COST-EFFECTIVENESS ANALYSIS-BASED ROAD CLASSIFICATION SYSTEM

The CEA-based road classification system includes four road classes: Basic Access Roads; Strategic Roads; Tactical Roads; and Surplus Roads. These classes are designed to identify roads that: primarily satisfy citizens' constitutional right to access basic services; maximise potential economic growth; and make a negative economic contribution.

6.3.1 Order of priorities

All South African citizens are legally entitled to the privileges enshrined in the *Bill of Rights* (South African Government, 1996). The *Bill of Rights* establishes the set of non-negotiable basic entitlements that the 1996 W*hite Paper on National Transport Policy* mandates the road network to support. Sections 27 and 29 of the *Bill of Rights* are particularly important as they proclaim that all citizens have the right to have access to health care services and basic education, respectively.

The argument for prioritisation of support for basic access is rooted not only in constitutional jurisprudence, but also in moral philosophy. Rawls (1971), Sen (2009), and Peffer (2008) argue that the primary good for a person, liberty, is based on the ability of a person to convert basic material endowments into good living and opportunities to pursue their objectives. But if people lack adequate access to basic amenities and essential services they are severely disadvantaged in this respect. Indeed, in the absence of a minimal threshold of such access, a life might not be worth living at all. A society that failed to allow some citizens to reach this threshold would therefore effectively sacrifice those people – perhaps for the sake of the more fortunate remainder of society if the needs of those sacrificed competed unavoidably with prerequisites for economic growth. A moral philosophy that licences such trade-offs is a variant of utilitarianism.

The three philosophers cited above reject utilitarianism. Peffer (2008) contrasts utilitarianism with the demands of what he calls the Basic Rights Principle, according to which: “everyone is to be guaranteed the standard range of resources needed for becoming and remaining a normally functioning human being and citizen, including standard – at least basic – health care (and assistance) and basic education, as well as adequate nutrition, potable water, minimally decent shelter and a liveable environment.” This position does not require equality of welfare or capability, but that citizens are entitled to the most extensive basic rights compatible with similar rights for others. In South Africa, this minimum level of access is based on department guidelines and access norms and standards.

The importance of economic growth must also be considered in a deep normative context. Because governments borrow against future growth, excessive spending on Basic Access Roads that choked off growth would erode the ability of the state to borrow. The amount of redistributive tax revenue government collects progressively falls if growth stalls. Economic growth is therefore essential if government is to maintain the fiscal capacity to sustain and grow expenditure on key public services that target the least well-off.

According to Rodrik (2007), “historically nothing has worked better than economic growth in enabling societies to improve the life chances of their members, including those at the very bottom.” Research that compares the experiences of a wide range of developing countries finds consistently strong evidence in support of Rodrik’s assertion that rapid and sustained economic growth is the single most important way to reduce poverty. Cross-country studies indicate that a 10.0% increase in a developing country’s average income typically reduces the poverty rate by 20.0% to 30.0% (DFID, 2008). Roemer and Gugetty (1997) regressed the growth of income for the poorest 20.0% and the poorest 40.0% of the total population of 26 developing countries against the GDP growth of these countries and obtained a similar, but more conservative, result. Gupta and Barman (2010) also provide empirical confirmation that economic growth and welfare are positively correlated, with their endogenous growth model indicating no conflict between the social welfare maximising solution and the growth rate maximising solution in the balanced growth equilibrium in an economy.

The level of economic growth in question, however, must be around the 6.0% targeted by the National Development Plan (NDP). Given that annual population growth is around 1.5% and government currently funds expenditure through debt, economic growth significantly less than the NDP target would mean per capita wealth is falling, or at best staying constant, and government would be unable to cover its debt service costs.

Given the importance of both basic access needs and economic growth, it is important to consider how to prioritise among roads that serve only one objective. The adopted approach takes it as given that basic rights are non-negotiable. This is precisely what makes them 'rights'. But this does not remove the need to justify the specific Rawlsian understanding of the role of rights in selecting allocation principles, or the need for a framework that reconciles their prioritisation with the urgent demand for support of economic growth.

6.3.1.1 *Rawlsian normative theory*

The Rawlsian normative framework puts basic rights and the welfare of the least well-off first in a lexicographical order of provisioning priorities. A lexicographical ordering stipulates a set of priorities to be addressed in order of descending importance, where the first priority must be fully satisfied or no longer applicable before the second priority can be addressed, and so on. The least well-off are defined as the most disadvantaged members of society, who in this case lack adequate access to the basic services that satisfy their fundamental human rights. To put their interests first would mean that Basic Access Roads are made the top priority. In contrast, well-off members of society already enjoy access to all basic services and therefore their interest is in higher economic growth. The poor share an interest in higher economic growth, and still more urgently. But the Rawlsian normative framework assumes that all lives must be made worth living before we ask how to make any of them better.

Rawls (1971) formulated a conception of justice intended to regulate the basic structure of society. The objective was to find principles for achieving balance between the competing claims of citizens and establishing a fair social contract that would be accepted by all. Rawls' theory of justice begins with two principles: firstly, each person is to have an equal right to the most extensive basic liberty compatible with a similar liberty for others; and secondly, social and economic inequalities are to be arranged so that they are both (i) to the greatest benefit of the least advantaged and (ii) attached to offices and positions open to all under conditions of fair equality of opportunity.

The first principle is referred to as the Liberty Principle, and puts liberty of conscience, the political liberty to vote and run for office, freedom from arbitrary arrest, and the freedom of speech, assembly and personal property first in the order of priorities. Rawls (1971) argues that in a just society basic liberties are not subject to bargaining, in fact not even the welfare of society as a whole can over-ride the loss of freedom for some.

The lexicographical ordering of the road classes is concerned with the first part of the second principle, called the Difference Principle, which demands that the welfare of the least well-off be maximised. The associated maximin criterion gives precedence to the welfare of the least well-off over the welfare of everybody else. While utilitarians are willing to let the poor get poorer if this makes the rich sufficiently richer, Rawlsian analysis tolerates no such sacrificial lambs.

Rawls (1971) defends the maximin principle using the following thought experiment: Imagine that the citizens of a society meet to plan a new social contract. Now imagine that a veil of ignorance is imposed, which hides from each person his or her particular, contingent place in society so that each person has equal cause to fear that they might become the victim of any injustice built into the final deal. Under these conditions, Rawls argues that each citizen would vote for a fair social contract that maximised the welfare of the least well-off.

Although the conclusion that an egalitarian baseline is intuitive in the circumstances of the original position proposed by Rawls, the reasoning has been subject to criticism, particularly from economists. A first basis for contestation pertains to the assumption that all members of society have the same 'rational' preferences and will therefore vote the same way if they are unaware of their particular material circumstances. This idea is problematic because it removes the point of bargaining. A stable social contract is one that members of society would collectively choose not because everyone has identical preferences – which they do not – but rather because it is in their self-interest to do so given the existence of a range of different preferences. It is this self-interest that will bind citizens to whatever they agreed upon behind the veil of ignorance once it is lifted.

Rawls also assumes that rational people are risk averse. Under the assumption that people are risk averse it is not sensible for anyone to take the risk of supporting a social contract that neglects disadvantaged citizens, lest they turn out to the be among the least well-off once the veil of ignorance is lifted. Rationality, however, entails no particular attitude toward risk. An individual who consistently prefers to accept risk is just as rational as someone who consistently seeks to minimise it.

Binmore (1994; 1998) agrees with the picture Rawls paints of the nature of a just society but finds that the arguments with which he defends his position fly in the face of sound economic logic. Binmore rather turns to game theory, in which bargaining outcomes are only internally stable if they establish a self-enforcing Nash equilibrium, to establish the considerations that would govern rational bargaining if citizens were to jointly choose a social contract. Binmore models bargaining over social contracts using an indefinitely repeated game, referred to as the Game of Morals. Essentially, the Game of Morals allows all players the option to renege on the decided social contract. If this option is exercised, players again go behind the veil of ignorance to negotiate the social contract to be operated in the future. Without an outside benevolent dictator to enforce an agreement, any contingent social contract that assigns substantive advantage to one player is untenable since nothing prevents the disadvantaged party from refusing to honour the deal. In Binmore's idealisation of this reality, all a bargainer has to do to exercise his option to renege on the social contract is insist on returning to the original position. In real life the dissatisfied inflict social costs on others in society through a range of more complicated forms of resistance.

Should citizens vote to improve the welfare of the relatively well-off, in this case by prioritising economic growth-orientated roads over Basic Access Roads, clear winners and losers are revealed once the veil of ignorance is lifted. The winners would be the well-off citizens who already had access to basic services and could therefore enjoy the benefits from economic growth. The least well-off would remain isolated from basic services, and in the face of this barely acceptable quality of life marginalised from any economic benefits.

To reach a stable equilibrium, players must recognise that they must make do with choosing from a feasible set of outcomes that do not incentivise some parties to reject a social contract and provoke a level of social strife that is more costly than the incentives required to keep them at the bargaining table. This feasible set of outcomes is termed a security strategy as it jointly yields the largest expected payoff. Binmore determines through analysis of this bargaining game that the only social contract that satisfies the requirement for an equilibrium in security strategies is one that maximises the welfare of the least well-off. In line with the arguments of Rawls (1971) and Sen (2009) the new social contract will typically not, and need not, establish a situation of equality. Egalitarian distributions, as applied to transport networks by Li *et al.* (2018), do not yield a security strategy that jointly yields the largest expected payoff. It is only necessary that the least well-off player receives sufficient compensation to ensure it is not in their interest to reject the agreement.

The effect of Rawls's appeal to the maximin criterion is obtained by abandoning altogether Rawls's claim that we have a natural duty to honour hypothetical deals reached in the original position. Players in the original position are not assumed to be absurdly cautious or to all have identical risk preferences. They confine their attention to the set of potentially stable agreements, where the welfare of the least well-off is maximised, because payoffs outside this set do not establish a Nash equilibrium and are therefore unavailable without a benevolent dictator to enforce the agreement. Since benevolent dictators are extremely rare and never reliable even when they briefly come along, a soundly organised society will avoid social contracts that rely on them. The constitutional principle that basic rights, which where roads are concerned are represented in basic rights of access, is supported by economic reasoning that, although highly idealised and abstract, is ultimately rooted in the practical necessities of maintenance of political stability and legitimacy. Road authorities should thus operate a road maintenance prioritisation policy that does not strand poor citizens without access to basic services.

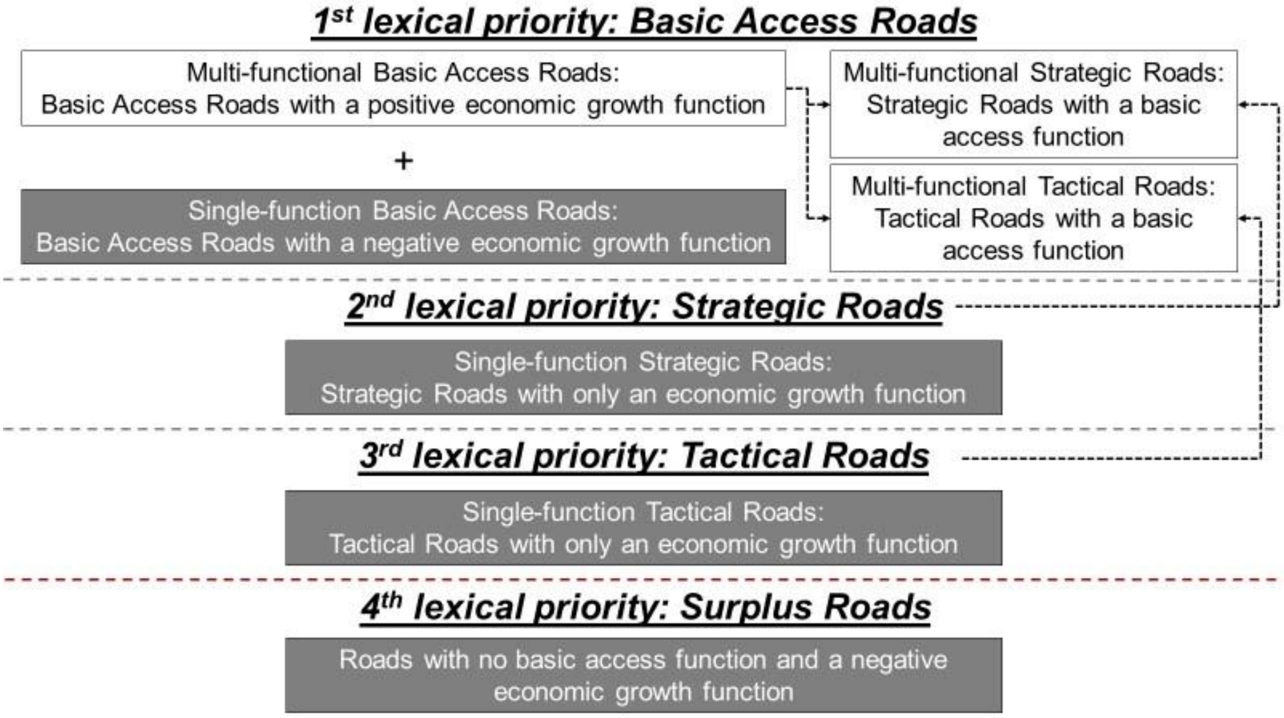
6.3.1.2 *Prioritisation rule*

The prioritisation rule for the four proposed road classes is shown in Figure 6.1 and reflects this Rawlsian normative reasoning. Basic Access Roads provide the only viable means for communities to access basic service centres, and in their absence citizens fall outside the prescribed norms and standards for access to these facilities. Basic Access Roads are thus set as the first lexical priority to ensure that all South Africans enjoy at least the minimum prescribed level of access to constitutionally protected primary and secondary schools and healthcare facilities. However, there is often a false dichotomy between these basic access and economic growth functions, with some roads, which we call 'multi-functional', essential for basic access whilst contributing to economic growth. Within Basic Access Roads, these Multi-functional Basic Access Roads must be prioritised before Single-function Basic Access Roads due to this dual function. Moreover, within Multi-functional Basic Access Roads the Multi-functional Strategic Roads must be prioritised over Multi-functional Tactical Roads as the former support higher levels of structural economic activity. Because the government's constitutional obligation prevents it from being able to trade off basic access for contribution to economic growth, Single-function Basic Access Roads must still be prioritised as the final call on resources within the top priority tier regardless of their negative contribution to growth.

Once citizens' rights of access to basic services have been protected through these Multi-functional and Single-function Basic Access Roads, the second lexical priority is roads that perform only an economic growth function. Single-function Strategic and Single-function Tactical Roads both perform just an economic growth function. Again, the Single-function Strategic Roads are prioritised over the Single-function Tactical Roads due to their larger contribution to expected economic growth. Single-function Tactical Roads are the final call on resources, following which road authorities would have satisfied their dual mandate.

Surplus Roads are the last priority. These roads fulfil no basic access function and make a negative economic contribution as the cost to maintain these roads exceeds the value of the economic activity they facilitate. Road authorities are advised to unproclaim Surplus Roads, thereby removing the risk that authorities might misdirect resources to these roads instead of more efficient allocation to higher priority roads.

Figure 6.1: Prioritisation rule



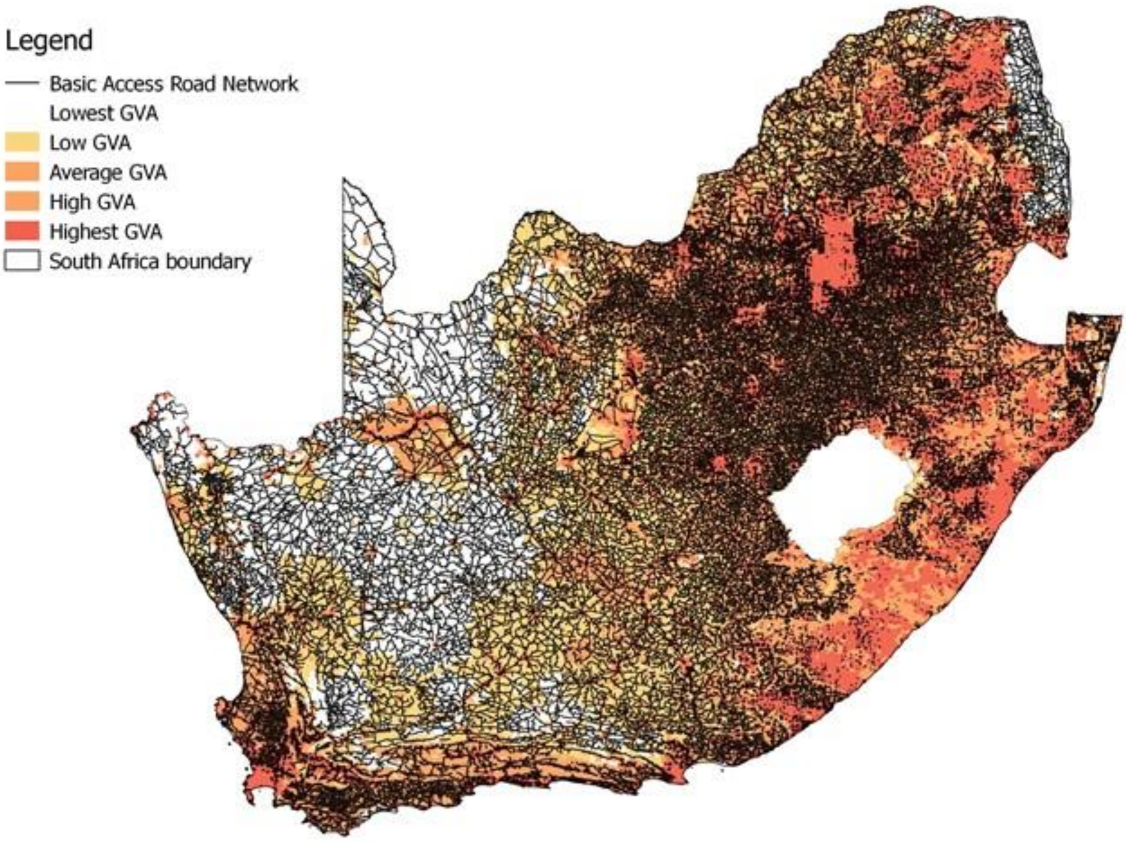
Source: Own.

6.3.2 Multi-functional and Single-function Basic Access Roads

Without the option of alternative access routes to basic service centres, isolated households are reliant on authorities to ensure that Basic Access Roads are maintained. The provision of these roads is a constitutional obligation, although Multi-functional Basic Access Roads also contribute to economic growth and Basic Access Roads in general help maintain rural-urban migration rates within manageable limits. As cyclical economic fluctuations have no bearing on the need for children to attend school or the number of people requiring medical attention to reach healthcare facilities, the demand elasticity for these roads is zero. While demand for these services should be seasonally consistent, controlling for the effects of migration and factors such as poor road conditions, a non-all-weather road surface, and the availability of public transport may force users to alter their travel patterns.

The procedure to identify the most efficient access routes between households and basic service facilities is to geospatially locate all households in the region and map which roads form the shortest route from residences (or closest point to it) to the nearest public primary and secondary school and healthcare facility. The potential Basic Access Road Network presented in Figure 6.2 was estimated using the 2011 Census data at the enumeration area level and GPS coordinates for the 25 137 registered ordinary and special needs primary and secondary schools and 5 389 healthcare facilities (Statistics South Africa, 2011; Department of Basic Education, 2017; National Department of Health, 2017).

Figure 6.2: The potential Basic Access Road Network, 2018



Source: Own calculations.

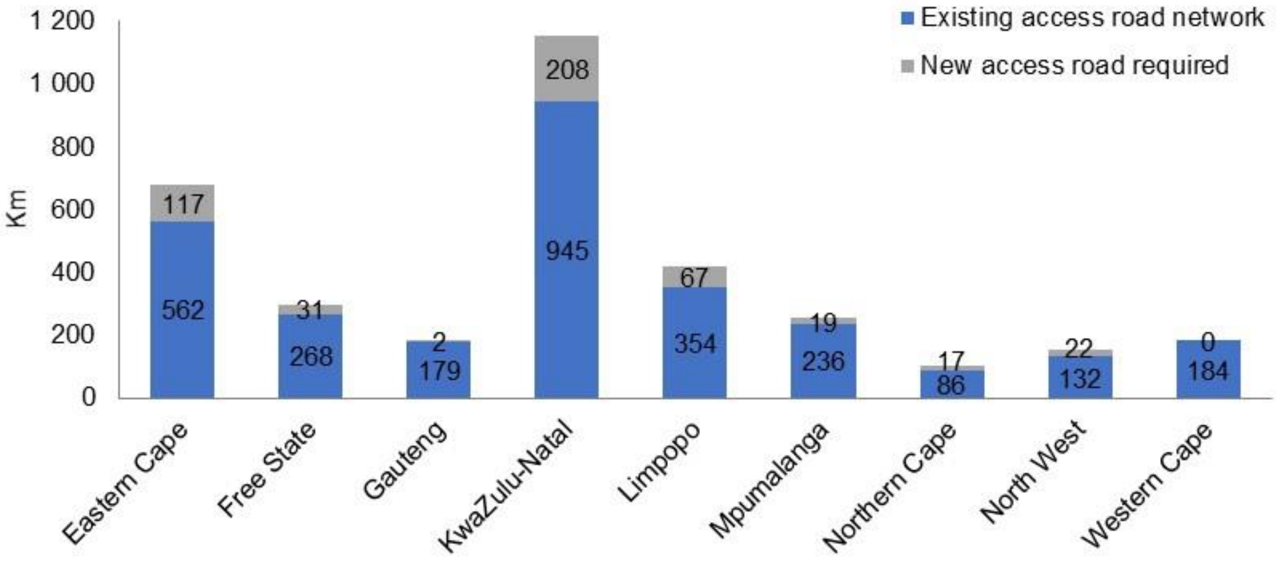
Two exclusionary conditions apply to Basic Access Roads and are factored into the potential Basic Access Road Network shown in Figure 6.2. Firstly, urban roads are excluded as Basic Access Roads due to the availability of alternative routes to service centres in these areas. Geospatial land use data, such as that prepared by the CSIR (2018), can be used to remove urban roads from the Basic Access Road Network. The naming hierarchy is another useful, albeit less accurate, reference as certain road names, such as Avenues, Lanes, and Streets, are generally associated only with urban areas.

Secondly, Basic Access Roads must fall outside the minimum prescribed level of access to the constitutionally protected basic education and healthcare facilities. The gazetted access norms and standards prescribe a feeder zone with a radius of 5.0 km for public primary and secondary schools (Government Gazette 33283, 2010). The 5.0 km feeder zone reflects the acceptable walking distance to schools, which creates a buffer within which authorities are not constitutionally required to provide access roads. Authorities may include specific direct access routes as part of the Basic Access Road Network given the importance of direct and all-weather road access to schools. No access standard exists for healthcare facilities, which is sensible as it is unreasonable to expect people requiring medical care to walk non-trivial distances.

As mentioned, some roads both fulfil a basic access function and contribute to economic growth. These multi-functional roads are efficient as they allow authorities to address access needs at the same time as promoting economic growth. Whilst overlapped basic access, strategic, and tactical road functions can occur in any rural and peri-urban setting, most of the multi-functional roads are likely to be in areas with higher economic activity. Using the CSIR's (2017) 2010 Gross Value Added (GVA) data, which is the most geospatially detailed dataset available for economic activity, Figure 6.2 illustrates the possible distribution of Multi-functional versus Single-function Basic Access Roads. The potential Basic Access Roads in regions with the lowest GVA account for less than 5.0% of the total road network, which suggests that most basic access demand can be addressed through multi-functional roads.

The NDOT (2018b) developed the *Access Road Development Plan* (ARDP) to assess the access road network in South Africa. The ARDP addresses the extent of the access road network, upgrades required to the current access road network, and requirements for future access roads. As illustrated in Figure 6.3, the NDOT identified 2 946 km of existing access roads and 483 km of new access roads required to provide rural communities with access to the following amenities based on the relevant access norms and standards: pre-primary, primary, and secondary schools; clinics, hospitals, and other medical facilities; libraries; post offices; South African Police Service; municipal offices; places of worship; sports facilities; and cemeteries. The NDOT's analysis therefore extends beyond access to constitutionally protected basic services, but nevertheless provides a useful benchmark to suggest that the potential Basic Access Road Network accounts for approximately 0.6% of the proclaimed road network. The NDOT also estimate that it would cost R1.6 billion per annum to address the maintenance needs of the access road network. This information leads to the important conclusion that authorities can maintain the Basic Access Road Network within the current budget parameters and still have significant budget to undertake maintenance of the Single-function Strategic Roads and Single-function Tactical Roads that respectively comprise the 2nd and 3rd lexical priorities.

Figure 6.3: Access road network identified by the NDOT, 2018



Source: National Department of Transport, 2018b.

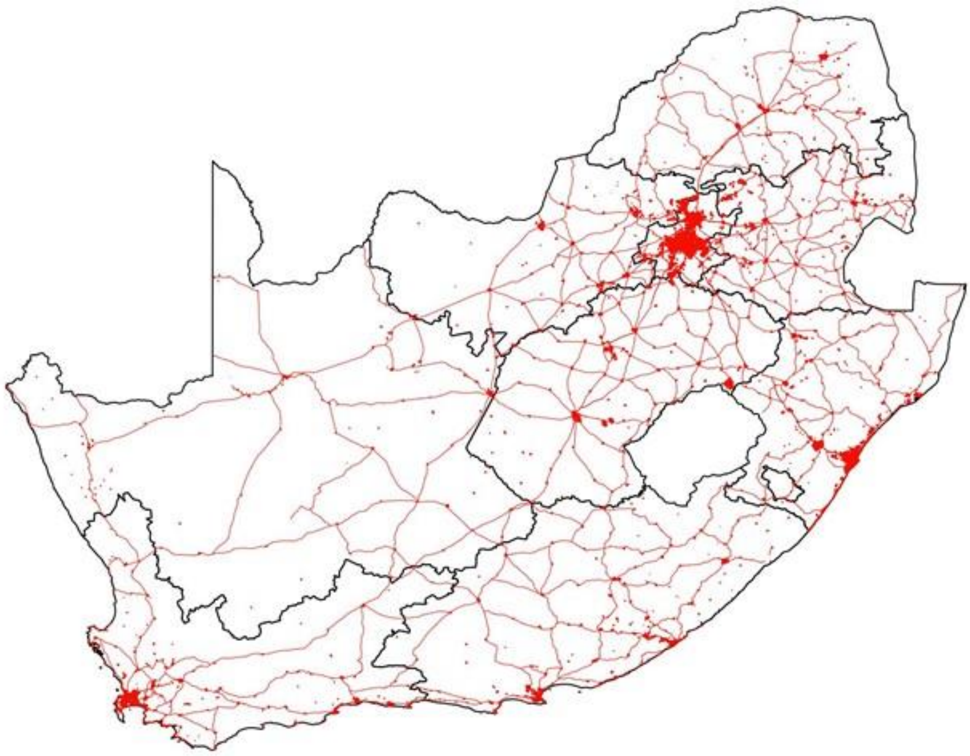
6.3.3 Strategic Roads

Strategic Roads include high value transport routes, which are generally within or between key regions and locations such as cities, major towns, international and local trade corridors, and high-volume freight and passenger terminals. While the concept of a Strategic Road Network is often used to refer to national roads, this network should extend to all roads that are core enablers of economic activity. SANRAL's (2015) Road Network Study identified a 9 200 km Core Strategic Network, 9 600 km Secondary Strategic Network, and 14 000 km Primary Road Network. The Secondary Strategic Network provides alternative routes to the Core Strategic Network, which are required in areas where low road density makes the Core Strategic Network difficult to reach. The Primary Road Network feeds the two strategic road networks. The Core Strategic Network and Secondary Strategic Network are designated as national roads, while the Primary Road Network is a combination of provincial and national roads. Importantly, user demand for Strategic Roads must be inelastic. Adding this criterion to Strategic Roads prioritises the maintenance of roads that make the highest contribution to economic growth over cyclical alternatives.

Urban roads, which have similarly inelastic demand to the Core and Secondary Strategic Networks and Primary Road Network, should also be classified as Strategic Roads. Urban roads combine to form integrated networks that support important daily mobility and access functions; including the transportation of goods consumed within urban boundaries and the movement of residents between homes, public facilities, and places of work. Incorporating urban roads into the Strategic Road Network aligns maintenance schedules with population density and trends in urban sprawl.

Figure 6.4 provides an approximation of the Strategic Road Network. This example of the Strategic Road Network combines the 32 800 km of Core Strategic, Secondary Strategic, and Primary Roads with all urban roads. The urban roads were identified by overlaying the CSIR's (2018) geospatial land use data with the total road network. Additional provincial and municipal roads may warrant inclusion in the Strategic Road Network following road specific analyses of the networks.

Figure 6.4: The estimated Strategic Road Network, 2018



<u>Source:</u> Own calculations.

Survey responses by senior provincial road officials and information from the 2017 provincial Road Asset Management Plans reveal that many authorities have based their strategic road networks on functional classifications. However, as discussed in Section 6.1, classification as a higher-order Class 1 or Class 2 mobility road provides insufficient economic information to warrant inclusion within the Strategic Road Network.

Again, prioritisation within the Strategic Road Network should not be necessary given the available resources in relation to the extent of this 2nd priority network. But if prioritisation within the Strategic Road Network is required then the Strategic Roads in rural and peri-urban areas must be separated from those in urban areas. The Strategic Roads in rural and peri-urban areas can be prioritised according to the road maintenance prioritisation model developed in Chapter 9. However, the complications associated with congestion require that the Strategic Roads in urban areas are prioritised through a separate process not covered by this thesis.

6.3.4 Tactical Roads

Tactical Roads are identified as rural and peri-urban roads that facilitate cyclical and low to medium levels of economic activity. The NDOT (2006) stress the importance of an effective Tactical Road Network for economic growth as the origin, transport route, and destination for many economic activities are located along secondary and tertiary roads that are not part of the Strategic Road Network.

Although Tactical Roads support a lower level of economic activity than Strategic Roads, it is imperative that roads in this class still make a positive contribution to economic growth. This determination should be based on a structural growth model that comprises two terms: the expected cost of the road; and the road's contribution to economic growth. The cost term should reflect the present value of the future cost of road maintenance, bearing in mind the finding from Chapter 7 that, due to the relative labour intensity of sealed road maintenance compared to gravel road maintenance, and the low shadow price of labour in parts of South Africa where there is scope for surface upgrades, roads worth maintaining are worth sealing.

6.3.5 Surplus Roads

Surplus Roads neither fulfil a basic access function nor contribute positively to economic growth, based on the structural growth model used to identify Tactical Roads. Because the present value of the cost to maintain these roads exceeds their economic contribution, the relevant authorities should unproclaim Surplus Roads and reprioritise any allocated funding towards the other productive classes. This action is permissible as none of these roads form part of a household's essential access route to basic service centres. Better value-for-money can therefore be achieved without violating any citizen's basic access rights.

The move to unproclaim Surplus Roads is supported by Dinwiddy and Teal's (1996) rebuttal of the convention that 'piling up' capital stock is the path to development. They reference examples to argue that the accumulation of capital assets can make a country poorer if the opportunity costs of these assets exceeds their rate of return. Ross and Field (2007) implore road authorities to evaluate streams of benefits and costs associated with road projects in terms of possible flows that could be realised were the resources spent on alternative road projects. This argument is especially relevant given the resource constraints within the roads sector, which mean that the opportunity cost of funding the maintenance of Surplus Roads is the alternative to maintain more Strategic or Tactical Roads depending on the available funding, which both provide relatively higher returns.

It is important to emphasise the need for authorities to formally unproclaim Strategic Roads, rather than simply neglecting their maintenance. Although the immediate budgetary effects of both decisions are similar for road authorities, neglecting the maintenance of a road has deadweight costs. For example, provincial education or health departments – which operate in isolation of the road departments – may decide to locate a school or clinic on a road slated for neglect. The provincial road departments, however, may be unwilling to unproclaim roads as network length is a determinant for the Provincial Roads Maintenance Grant allocation.

6.4 CONCLUSION

The CEA-based road classification can be easily added as a decision variable in the asset management systems by pairing the road IDs with the relevant class. The intention is not to overwrite the existing classification data as these serve specific purposes, but rather to complement the engineering variables in the asset management systems which currently include visual condition, roughness, rut depth, macro texture, deflections, and traffic. These technical variables prescribe remedial works, which budget allocation systems reference to allocate the limited resources in a way that minimises the whole life cost of the network. This often means that roads in better condition are prioritised for maintenance, as delayed routine and periodic maintenance exponentially increases project costs, and deteriorated roads are ignored. While the same strategy might still apply, the CEA-based classification system ensures that authorities set their maintenance schedules with full information about which roads they have a constitutional obligation to maintain, which roads support high levels of economic activity, which roads support lower levels of cyclical economic activity, and which roads make a negative economic contribution.

The analysis of the CEA-based road classification system draws two critical findings. Firstly, less than 5.0% of potential Basic Access Roads are in regions of the country in the lowest GVA category. This suggests that a high proportion of the demand for access to basic services can be provided through multi-functional roads. Second is the NDOT's finding that the access road network accounts for about 0.6% of the proclaimed road network and will cost approximately R1.6 billion per annum to maintain. These pieces of information indicate that authorities can maintain Single-function Basic Access Roads within current budget parameters with significant budget still available to maintain Multi-functional Basic Access Roads and Single-function Strategic and Tactical Roads.

Alternatively, were road authorities to adopt the opposite approach to that set for the CEA-based road classification system and prioritise Single-function Strategic Roads and then Single-function Tactical Roads before Single-function Basic Access Roads, it is unlikely that sufficient budget would remain to maintain the Basic Access Roads on which the poorest citizens rely to access constitutionally protected basic services. The evidence thus supports the appropriateness of the CEA-based road classification system and highlights the need to minimise the maintenance cost imposed by the Single-function Basic Access Roads and to develop a model to inform prioritisation decisions amongst Tactical Roads, which form the final call on resources and therefore the likely focus of the prioritisation exercise.

7 OPTIMAL SURFACING POLICY FOR LOW-VOLUME ROADS

73.6%, or 454 609 km, of South Africa's proclaimed road network is unsealed. Within this unsealed road network approximately 90.8% of roads carry less than 250 vehicles per day (VPD) and 84.3% carry less than 100 VPD (National Treasury, 2018a). Although unsealed roads facilitated only 5.6% of the vehicle-kms travelled on the proclaimed road network in 2017, the provincial and municipal road authorities who manage unsealed roads cannot just overlook their maintenance in favour of higher-volume surfaced roads as some positively contribute to economic growth or provide citizens with their only feasible means to access constitutionally protected basic services (National Treasury, 2018a).

In the absence of a national road surfacing policy, road authorities have based their strategy on the HDM-4 derived guideline that Annual Average Daily Traffic (AADT) must exceed 200 vehicles to justify upgrading an unsealed road to a surfaced standard. But in practice many unsealed roads are only upgraded to a surfaced standard once AADT exceeds 500 or 1 000 vehicles. In contravention of this tradition is a trend, which to-date has been followed by at least 18 developing countries and explored by 5 of South Africa's provincial road authorities, towards surfacing unsealed roads irrespective of the traffic volume to eliminate regravelling and minimise the maintenance requirements over the life of a road (Botswana Ministry of Works, Transport & Communications, 1999; KZN Provincial Planning and Development Commission, 1999; Paige-Green and Hongve, 2003; Oloo et al., 2003; Naidoo et al., 2004; Paige-Green et al., 2004; Cook and Petts, 2005; Goeltam, 2007; Transportation Research Laboratory, 2008; Kackada and Cook, 2009; Paige-Green, 2012; Pinard and Overby, 2013; Joshi and Jah, 2013; Malawi Ministry of Transport and Public Works, 2013; Muzira and de Diaz, 2014; Mukura, 2014; Tanzanian Ministry of Works, Transport and Communication, 2016; Ethiopian Roads Authority, 2016; Rolt et al., 2017; Eastern Cape Department of Roads and Public Works, 2017; International Bank for Reconstruction and Development, 2018; Kenya Rural Roads Authority, 2018; Western Cape Department of Transport and Public Works, 2018; South African National Parks, 2018).

This trend in surfacing unsealed roads is relevant to road authorities for 3 main reasons: the high maintenance intensity of gravel roads has led to sharply reduced service levels on the unsealed road network despite large annual budget allocations; road authorities face severe fiscal and human resource constraints; and factors that escalate the frequency and cost of works on unsealed roads are common across South Africa. This paper therefore compares the estimated cost to provide low-volume gravel and light bituminous seal roads to determine an optimal national road surfacing policy. Light bituminous seals are represented here by a 14 mm cape seal with 1 slurry as this surface is well suited to labour-intensive practices, is less sensitive to imperfections in the base layer, and has proved structurally robust in local conditions (SANRAL, 2007). But once a policy position is reached on whether sealing gravel roads is optimal, it remains for the respective road managers to specify the appropriate seal for a specific road project.

Section 7.1 introduces the lifecycle cost analysis (LCCA) methodology. Section 7.2 presents the data used to estimate the lifecycle costs for gravel and cape seal roads and to specify their respective production functions. Section 7.3 reviews the LCCA results, including the stress tests that account for actual variances in the environmental and market conditions in South Africa. Section 7.4 mentions additional cost factors that were not considered in the LCCA due to data limitations. Although these additional cost factors are expected to further motivate a policy to seal gravel roads, they stand as areas for future research. Section 7.5 addresses major welfare benefits that might accrue from sealing gravel roads, most notably the positive impacts on employment, skills and contractor development, substitution of local resources for imports, rural-urban migration, and all-weather road access to basic services. Section 7.6 concludes by summarising the policy finding that authorities should seal gravel roads worth maintaining at a rate possible within budget limitations, bearing in mind the point from Chapter 6 that not all roads will satisfy the criteria for maintenance.

7.1 LCCA METHODOLOGY

LCCA is an analytical technique that uses initial and discounted future costs to evaluate the overall long-term economic efficiency of alternative investment options (Walls and Smith, 1998). This analysis provides critical information to inform investment decisions and has been endorsed by several organisations including the Department of Transport (2013), CSIR (1993), and United States Federal Highway Administration (2019). Here the LCCA will be used to compare the whole-life cost of the following low-volume road categories: new gravel and lightly sealed roads; gravel roads in good condition; and gravel roads in poor condition.

The reviewed costs include all the differential planning, design, construction, maintenance, rehabilitation, and salvage costs. Salvage costs refer to the serviceable life of a road at the end of the analysis period, which is calculated as the remaining serviceable life as a prorated share of the last rehabilitation cost, and are netted from the other costs to estimate the total lifecycle cost for each alternative road surface (Caltrans, 2011). Based on these variables the Present Value (PV) of costs is calculated as follows:

$$PV = C + \sum_{i} M_i \, (1 + r)^{-x_i} - S(1 + r)^{-z} \quad 7.1$$

where *PV* is the present value of all costs, *C* is the present cost of the initial construction, M_i is the cost of the ith maintenance or rehabilitation measure, *r* is the real discount rate, x_i is the number of years from the present to the ith maintenance or rehabilitation measure, *z* is the analysis period over which the road surfaces are evaluated, and *S* is the salvage value of the road surface at the end of the analysis period.

The analysis period is set at 30 years to cover the longest design life, incorporate at least one major rehabilitation activity for each road surface, and reflect long-term cost differences associated with the alternative road surfaces (Walls and Smith, 1998). The discount rate is set at 10.0%, which reflects the National Treasury's working rate of 9.0% and Kuo *et al.'s* (2003) economic opportunity cost of capital (EOCK) estimate for South Africa of 11.0%. However, it would be interesting to redo this LCCA using a more sophisticated ecological discount rate (EDR), as proposed by Gollier (2010; 2011a; 2011b) and Echazu *et al.* (2012), that accounts for the substitutability between environmental assets and consumption and the uncertainty that affects the dynamics of consumption and the environment. Under this method, the environmental impacts of a road project are separated from the other impacts and subject to a specific EDR that is typically significantly lower than the EOCK. Separating environmental impacts from other impacts and applying an EDR to the former and the EOCK to the latter is more accurate than using a single, lower discount rate to assign larger present values to environmental impacts – as done by many policy-makers. The application of an artificially low opportunity cost discount rate risks distorting the technology choice decisions in favour of capital-intensive solutions. The discounting element of this LCCA thus stands as an area for future work should the necessary information for an EDR become available.

Values for the cost variables could not be determined probabilistically due to data limitations (National Treasury, 2018a). A deterministic approach is therefore adopted in which fixed, discrete costs are applied for each variable based on evidence and professional judgement of what value is likely to occur (Rahman and Vanier, 2004). These fixed costs are then collectively applied to estimate the lifecycle cost of the alternate road surfaces. Sensitivity analyses are performed on selected assumptions made for key cost variables to account for uncertainty of the outcomes. Although the deterministic approach precludes simultaneous variations in multiple inputs and simplifies the degree of uncertainty with lifecycle cost estimates, it is the appropriate method if there are data constraints and as such is applied in two-thirds of the transport LCCA studies reviewed by Korpi and Ala-Risku (2008).

7.2 ROAD SPECIFICATIONS AND DATA

7.2.1 Road and pavement design

The cross-sections reflect class 3 roads, which are the lowest class of sealed road (Western Cape Government, 2006). Such roads have two 3.4 m surfaced lanes, two 0.9 m surfaced shoulders, and two 0.6 m roundings constructed to the same standard as the lanes. Class 4 roads have the same cross-section except they are unsurfaced. The LCCA also accounts for the fact that many existing gravel roads are only 6.0 m wide.

Additional pavement layers are not modelled for roads with a G6 or G7 in situ subgrade as these materials have been declared suitably strong for the gravel wearing course or seal to be laid directly on the road formation (Department of Transport, 2013). In the case of weaker in situ subgrades, additional pavement layers reflect the TRH 4 specifications and Western Cape Government's (2006) Geometric Manual for Class 3 and 4 roads with a design bearing capacity of 0.1 - 0.3 million equivalent standard axles (ES0.3) per lane (COLTO, 1996). The untreated ES0.3 pavement cross-section is divided into 5 elements, which similarly apply to gravel and surfaced roads except for the base layer which is not necessary for gravel roads: 150 mm subgrade consisting of G10 gravel or soil; 150 mm selected consisting of G9 gravel or soil; 125 mm subbase consisting of G6 natural gravel; 125 mm base consisting of G4 crushed or natural gravel; and a gravel wearing course or bituminous seal.

7.2.2 Condition index trigger method

The unsealed road network had the following Visual Condition Index (VCI) profile in 2017: 2.3% in very good condition; 4.6% in good condition; 15.6% in fair condition; 44.1% in poor condition; and 33.4% in very poor condition. These VCI categories are respectively grouped into initial roadwork categories in Table 7.1 according to the TRH 4 condition index trigger method, which prescribes routine maintenance for roads in good and very good condition, periodic maintenance for roads in fair condition, and major rehabilitation or reconstruction for roads in poor and very poor condition (Committee of Transport Officials, 1996). Major rehabilitation applies to 77.5% of the unsealed road network and is the main work activity.

Table 7.1: Proclaimed unsealed roads per initial maintenance category, 2017

Roadwork category	Condition (VCI)	Length (km)
Routine maintenance / Periodic maintenance	Very good and good	31 319
Periodic maintenance / Minor rehabilitation	Fair	70 990
Major rehabilitation	Poor	200 269
Major rehabilitation / Reconstruction	Very poor	152 032

Source: Own calculations.

7.2.3 Roadwork activities and costs

The unit cost data are from the National Treasury's (2018a) Road Network Cost Model. The data for this Model were compiled according to the following 4-step process: a first principles approach was adopted in consultation with three experienced pavement engineers to derive competitive task rates and unit costs for the categories of roadworks on roads with different surfaces, traffic volumes, and conditions; the task rates and unit costs were cross-checked against the tender documents collected as part of the Provincial Roads Performance and Expenditure Review and the data reported in the provincial Road Asset Management Plans (RAMPs) and Department of Transport's (2018b) Access Road Development Programme; a second cross-check of the task rates and unit costs was performed by the Southern African Bitumen Association for research outputs that applied the data; and a final verification was performed by the National Treasury, which sent the data to provincial road departments for comment. The Model was finally distributed to the provincial road departments as a tool to evaluate project specifications and tenders.

Table 7.2 presents the average construction and maintenance costs for low-volume roads surfaced with a cape seal under different local conditions. Steep road gradients are between 5.1% and 12.0%, while high moisture regions score above 20 on the Thornthwaite Moisture Index. The CSIR (1993) and Department of Transport (2013) claim that the in situ subgrade is strong enough to support low-volume roads without additional pavement layers in many regions of South Africa. However, in cases where this is not possible the specified pavement structure must be constructed. The typical preventative maintenance strategy for cape seals comprises annual routine maintenance, resealing in year 10, and rehabilitation in year 20.

Table 7.2: Typical construction and maintenance unit costs for cape seal roads, 2018

Activity	Cost per km (R)		
	Moderate conditions	Steep gradient	High moisture
Construction: In situ base	1 800 000	2 430 000	2 160 000
Construction: Pavement	4 000 000	6 000 000	5 960 000
Routine maintenance	100 000	100 000	100 000
Reseal	1 100 000	1 375 000	1 320 000
Rehabilitation	1 800 000	2 430 000	2 160 000

Source: National Treasury, 2018a.

Table 7.3: Typical construction and maintenance costs for gravel roads, 2018

Activity	Cost per km (R)					
	Moderate conditions		Steep gradient		High moisture	
	6.0 m	6.8 m	6.0 m	6.8 m	6.0 m	6.8 m
Construction: In situ base	705 880	800 000	1 058 820	1 200 000	882 350	1 000 000
Construction: Pavement	2 647 050	3 000 000	4 420 574	5 010 000	4 499 985	5 100 000
Routine maintenance	100 000	100 000	180 000	180 000	180 000	180 000
Periodic maintenance	264 705	300 000	397 058	450 000	330 881	375 000
Rehabilitation	705 880	800 000	1 058 820	1 200 000	882 350	1 000 000

Source: National Treasury, 2018a.

Table 7.3 presents the construction and maintenance costs for low-volume gravel roads under the same set of conditions. Again, road construction can occur on a suitably strong in situ base or specified pavement structures. Construction is replaced by routine maintenance for roads in good condition or rehabilitation for roads in poor condition. The annual routine maintenance typically consists of quarterly blading events, with an 8-year rehabilitation cycle based on the gravel thickness specified in TRH 20 and average annual gravel loss of 12 mm. Variations in the rate of gravel loss affect the timing of maintenance and rehabilitation work.

7.2.4 <u>Factor inputs</u>

Based on the National Treasury's (2018a) cost data, equations 7.2, 7.3, and 7.4 respectively detail the typical 30-year construction and maintenance inputs for cape seal roads, gravel roads in good condition, and gravel roads in poor condition for regions with strong in situ subgrade. The production functions all have constant returns to scale.

$$Y = AK^{0.34}L^{0.21}M^{0.35}B^{0.04}F^{0.06} \qquad 7.2$$

$$Y = AK^{0.37}L^{0.22}M^{0.34}F^{0.07} \qquad 7.3$$

$$Y = AK^{0.38}L^{0.27}M^{0.30}F^{0.05} \qquad 7.4$$

where *Y* is output measured in terms of kilometres of road, *A* is factor productivity, *K* is capital, *L* is labour, *M* is materials, *B* is bitumen, and *F* is fuel.

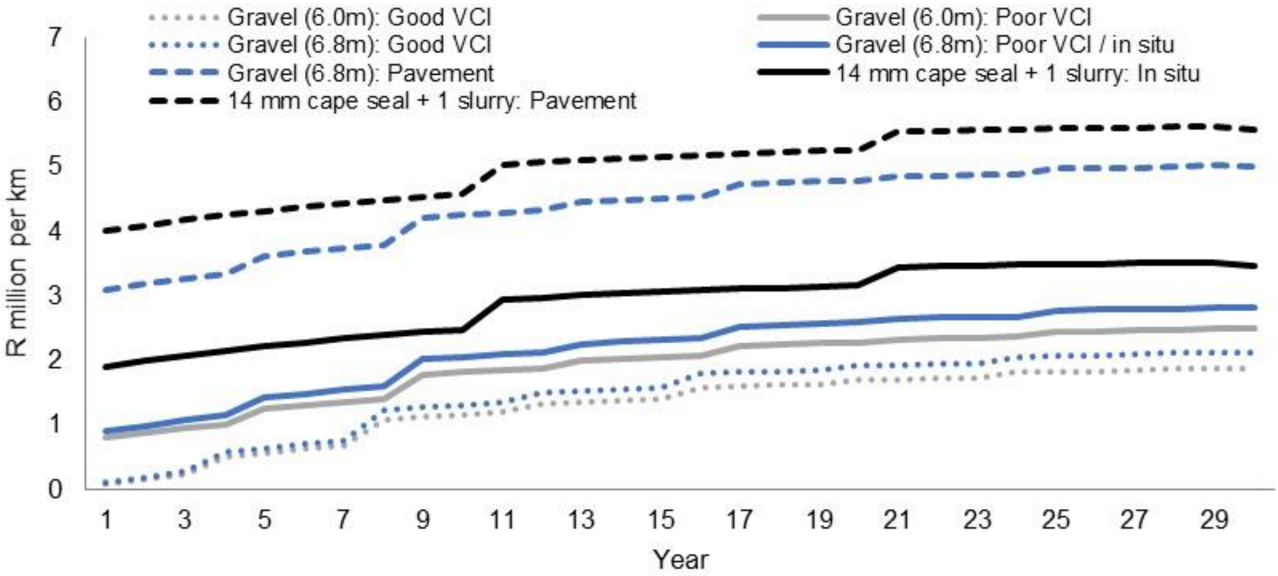
7.3 LIFECYCLE COST ANALYSIS RESULTS

The following factors inform road surfacing decisions under the Environmentally Optimised Design (EOD) approach: available materials; operational environment; road task; and the natural environment (Pinard and Overby, 2013). The International Bank for Reconstruction and Development (2018) argues that environmental factors are the primary determinant of pavement deterioration for roads carrying less than 1.0 million equivalent standard axles. EOD acknowledges that these factors vary along and between roads and hence a range of options must be considered. The Road Infrastructure Strategic Framework for South Africa also avoids specifying a rigid surfacing algorithm (National Department of Transport, 2006). The LCCA therefore investigates the relative cost-effectiveness of gravel and cape seals for the range of conditions experienced across the South African road network. The result is a proposed national surfacing policy for low-volume roads.

7.3.1 Simplistic baseline conditions

The baseline scenario illustrated in Figure 7.1 reflects almost ideal conditions for gravel road provision, which few regions in South Africa approximate. Under this ideally simple world for road surfacing decisions the road gradient is flat, climate is moderate, average haulage distance is 7.0 km, average annual gravel loss is 12 mm, and grading happens 4 times per annum. When conditions are conducive to gravel road provision the LCCA finds that existing gravel roads, regardless of their initial condition, are more cost-effective than cape seals. Although recurrent regravelling lowers the opportunity cost between gravel and sealed roads over the period, the savings in the construction of gravel roads is the dominant factor once discount rates are considered. However, national road surfacing policy should not be driven by the ideally simple case, but rather by reference to tendencies in the relationship between complicating factors and relative surface construction and maintenance costs.

Figure 7.1: LCCA under simplified baseline conditions



Source: Own calculations.

7.3.2 Steep road gradients

The erosion of gravel road surfaces is problematic in rolling or mountainous terrain where the gradient is relatively steep. TRH 20 explains that erosion of gravel roads can be lessened by decreasing the grade and cross-fall of the road and minimising the length of the flow path of the water (Department of Transport, 1990). To remove water to the side of the road and prevent it flowing down the full length of the grade the cross-fall must exceed the longitudinal grade, up to a maximum of 5.0%. Gravel roads with longitudinal slopes or cross-falls above 5.0%, or 4.0% if the road carries large vehicles and is winding or narrower than 7.0 m, are therefore prone to erosion.

Erosion rates on gravel roads with steep gradients can be partially reduced by improving the shear strength of the wearing layer through adequate compaction, grading, and gravel size. But measures to improve shear strength escalate the cost of road provision, which leads TRH 20 to conclude it is not cost-effective to avoid erosion on sections of gravel road with steep gradients. Table 7.4 details the extent to which steep road gradients raise the input factors relative to the baseline production functions. It is important to note that capital, labour, materials, and fuel inputs increase proportionally more for gravel than for sealed roads.

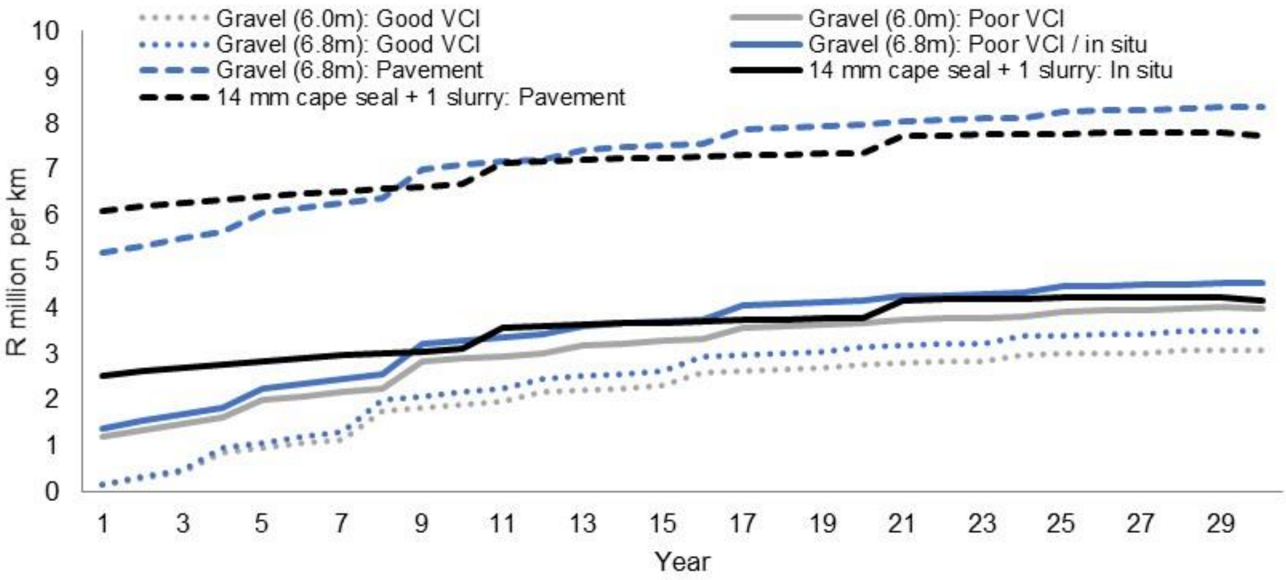
Table 7.4: Lifecycle change in input factors relative to the baseline for roads with a steep gradient

Input factor	Gravel: Poor condition	Gravel: Good condition	Cape seal
Capital (*K*)	*99.7%*	*94.6%*	*47.7%*
Labour (*L*)	*67.4%*	*71.8%*	*1.8%*
Materials (*M*)	*26.4%*	*29.9%*	*17.1%*
Fuel (*F*)	*7.0%*	*7.0%*	*6.0%*
Bitumen (*B*)	N/A	N/A	*14.9%*

Source: Own calculations.

Based on these changes in input factors, keeping the other baseline conditions constant Figure 7.2 indicates the effect that a steep road gradient, between 5.1% and 12.0%, has on the cost-effectiveness of the alternative road surfaces. Steep gradients make it cost-effective to seal 6.8 m wide gravel roads in poor and very poor condition when the in situ subgrade is good, with the upgrade payed off by year 9. If the road gradient is steep it is also cost-effective to seal new roads requiring a traditional pavement design.

Figure 7.2: LCCA with a road gradient between 5.1% and 12.0%



Source: Own calculations.

7.3.3 High moisture environments

While the structural layers of surfaced roads are largely protected from environmental effects by the application of a waterproof layer, the structural layers of gravel roads are exposed to environmental forces (Department of Transport, 2013). The bulk of rainwater must therefore be removed from the road surface before it erodes the gravel wearing layer or infiltrates the pavement structure. This requires frequent road maintenance to ensure that the road has a compact, tightly bound wearing course, definite crown, adequate cross-fall, and no potholes, corrugations, or ruts. Thicker pavement structures to improve the bearing capacity of a road, more sophisticated subsoil drains, and deeper side drains are also potentially required for both gravel and surfaced roads in high moisture environments.

Although the effects of high moisture on gravel road surfaces can be controlled, Petts (2002) argues that the additional funding to do so raises sustainability concerns. This concern is demonstrated by Table 7.5, which details the change in input factors relative to the baseline production functions to provide gravel and cape seal roads in high moisture regions. Such regions, which typically have a Thornthwaite Moisture Index score above 20, are mostly in the Eastern Cape, KwaZulu-Natal, Limpopo, Mpumalanga, and Western Cape provinces. For example, 5 113 km or 36.9% of provincial roads in Mpumalanga are reportedly affected by high moisture (Mpumalanga Provincial Government, 2016). Again, the relative changes to all common input factors are higher for gravel than sealed roads.

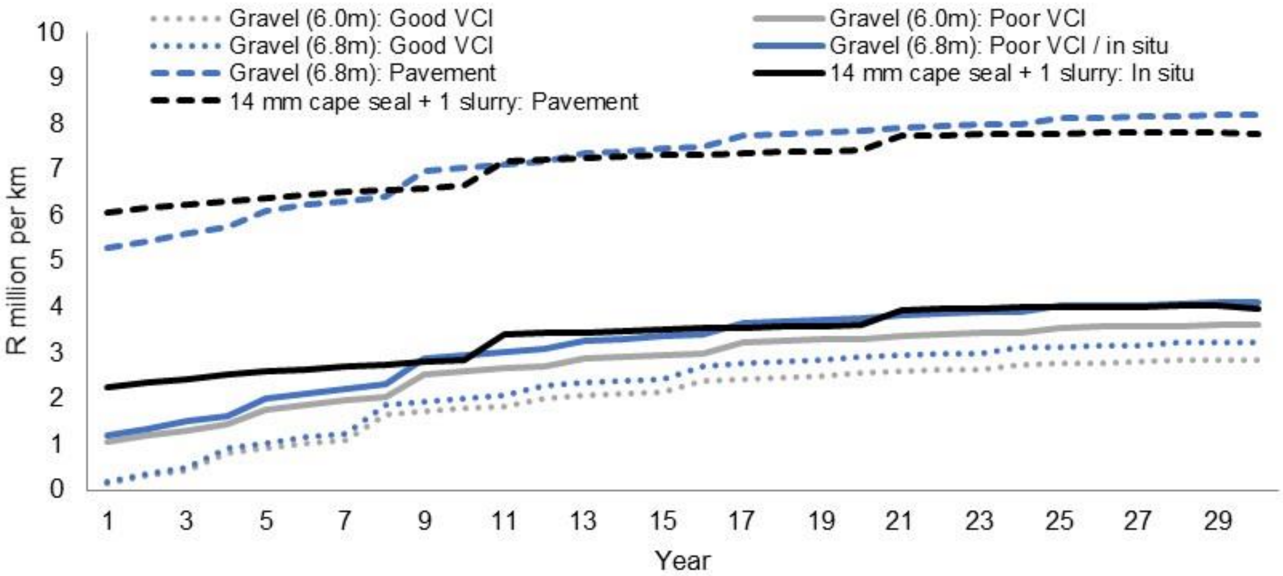
Table 7.5: Lifecycle change in input factors relative to the baseline for roads with high moisture

Input factor	Gravel: Poor condition	Gravel: Good condition	Cape seal
Capital (*K*)	*56.2%*	*60.5%*	*30.1%*
Labour (*L*)	*67.4%*	*71.8%*	*1.8%*
Materials (*M*)	*26.3%*	*29.9%*	*7.0%*
Fuel (*F*)	*8.0%*	*8.0%*	*6.1%*
Bitumen (*B*)	N/A	N/A	*18.7%*

Source: Own calculations.

The baseline conditions are maintained in Figure 7.3 except for climate, which now reflects a high moisture region. Although a high moisture environment increases the lifecycle costs for both road surfaces, the LCCA indicates that when the in situ subgrade is good it is cost-effective to seal 6.8 m wide gravel roads in poor and very poor condition, with the upgrade paid off by year 9. It also becomes cost-effective to seal new roads requiring a traditional pavement design, with an estimated payoff period of 8 years.

Figure 7.3: LCCA in areas with high moisture



Source: Own calculations.

7.3.4 High rates of gravel loss

The provision and ongoing replacement of gravel road surface materials poses a significant cost. TRH 20 specifies that proclaimed gravel roads should comprise a 100 mm to 150 mm layer of gravel, which can rise to 200 mm for higher traffic volumes, with a minimum buffer thickness of 25 mm to 50 mm (Department of Transport, 2013). The baseline scenario set annual gravel loss at 12 mm according to typical experience and the prescribed minimum regravelling frequency in TRH 20 of 7 to 10 years. But many gravel roads in South Africa have higher rates of gravel loss due to their specific road traffic, climate conditions, and material properties. For example, average annual gravel loss for some roads in the Western Cape province is between 25 mm to 50 mm, with extreme cases reaching 255 mm (Western Cape Department of Transport and Public Works, 2016; 2018). Moreover, average annual gravel loss in KwaZulu-Natal province varies between 5 mm to 75 mm (CARNS Consulting Group, 1997). The regravelling cycle can therefore be as short as 5 months.

Table 7.6 illustrates the change in input factors relative to the baseline production functions when the average annual rate of gravel loss increases to 25 mm. This higher rate of gravel loss shortens the regravelling cycle from 8 to 4 years. A relatively large increase in all input factors is required for gravel roads in both good and poor condition. The largest increases are for fuel and basic materials.

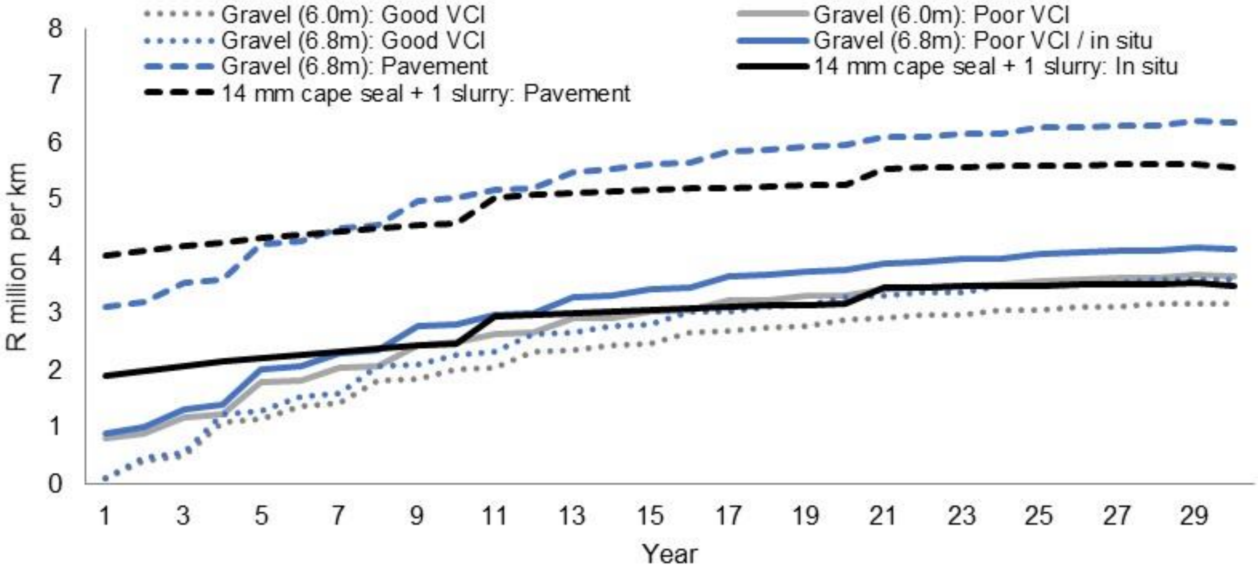
Table 7.6: Lifecycle change in input factors relative to the baseline for roads with high gravel loss

Input factor	Gravel: Poor condition	Gravel: Good condition	Cape seal
Capital (*K*)	*45.2%*	*65.0%*	N/A
Labour (*L*)	*12.8%*	*15.3%*	N/A
Materials (*M*)	*66.2%*	*114.9%*	N/A
Fuel (*F*)	*74.0%*	*137.6%*	N/A
Bitumen (*B*)	N/A	N/A	N/A

Source: Own calculations.

Maintaining the baseline conditions, Figure 7.4 shows the effect that increasing the average annual rate of gravel loss from 12 mm to 25 mm has on the relative cost-effectiveness of gravel roads. Despite being lower than the highest observed rates of gravel loss, this change is enough to cause cape seals to become more cost-effective than gravel for most roads. The LCCA indicates that for regions with strong in situ subgrade it is cheaper to seal 6.0 m and 6.8 m wide gravel roads in poor and very poor condition, as well as 6.8 m wide gravel roads in good condition. New roads requiring a traditional pavement design should also be sealed, with this decision paid off by year 7.

Figure 7.4: LCCA when the annual rate of gravel loss is 25 mm



Source: Own calculations.

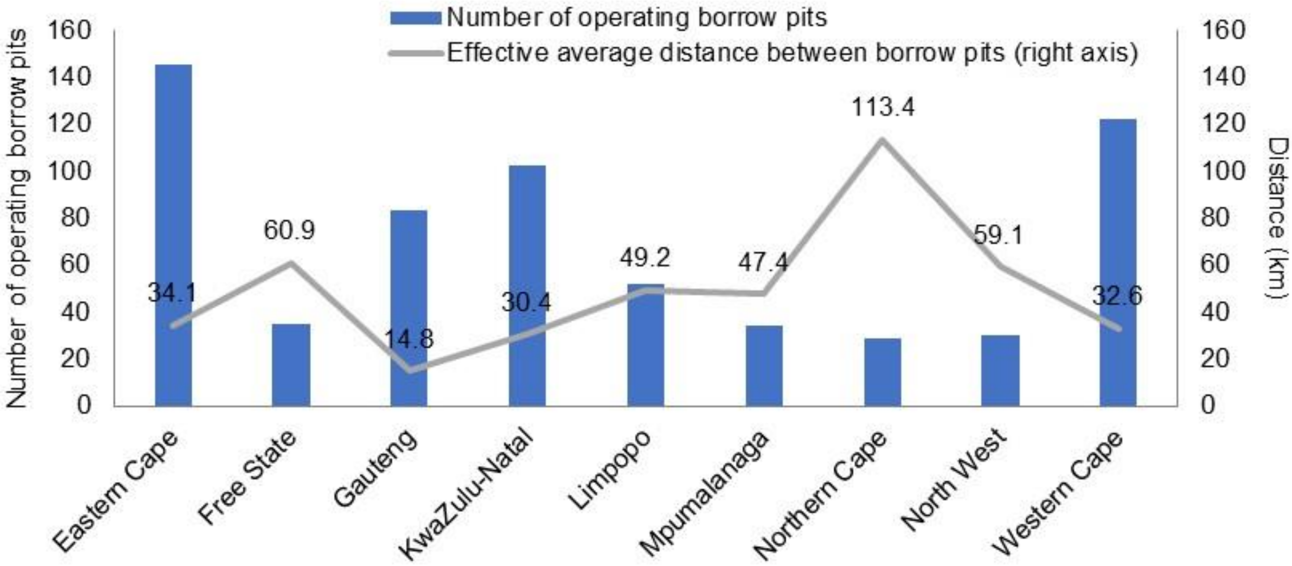
7.3.5 Extended gravel haulage distances

The Department of Transport (2013) and SANRAL (2013) express concern that many areas in South Africa lack sufficiently high-quality gravel materials for gravel road surfaces. Even where geology is suitable for wearing course gravel, significant drawdowns on this material over the past 6 decades have reduced reserves to the extent that often only substandard materials remain (Western Cape Department of Transport and Public Works, 2017). Hence the prediction in TRH 20 that the quantity and quality of gravel materials will deteriorate.

The supply of gravel materials is also complicated by legal and environmental pressures. SANRAL (2013) contends that the *2002 Minerals and Petroleum Resources Development Act* constrains the identification and exploitation of granular material used for gravel roads by requiring borrow pits to be registered and run as mines. The 10-step process to identify, prove, authorise, operate, and close a borrow pit includes an Environmental Management Programme that must be agreed to by all stakeholders and approved by the Department of Mineral Resources for mining to occur. It typically takes between 6 to 24 months to obtain environmental and mining approval, which further constrains authorities' ability to source quality materials and optimally space borrow pits across their road networks.

These resource and regulatory restrictions have led to a more uneven spread of borrow pits and longer haul distances. Figure 7.5 presents the Department of Mineral Resource's (2019) January 2019 statistics for the number of operating mines that produce gravel materials for road surfacing. The shortest effective average spacing between borrow pits is 14.8 km in Gauteng province, with this distance rising to 113.4 km in the Northern Cape province. The Northern Cape Department of Roads and Public Works (2017) link excessive haul distances, which they confirm can exceed 50.0 km, to the fact that gravel deposits in many areas are non-existent, on inaccessible land, or exhausted.

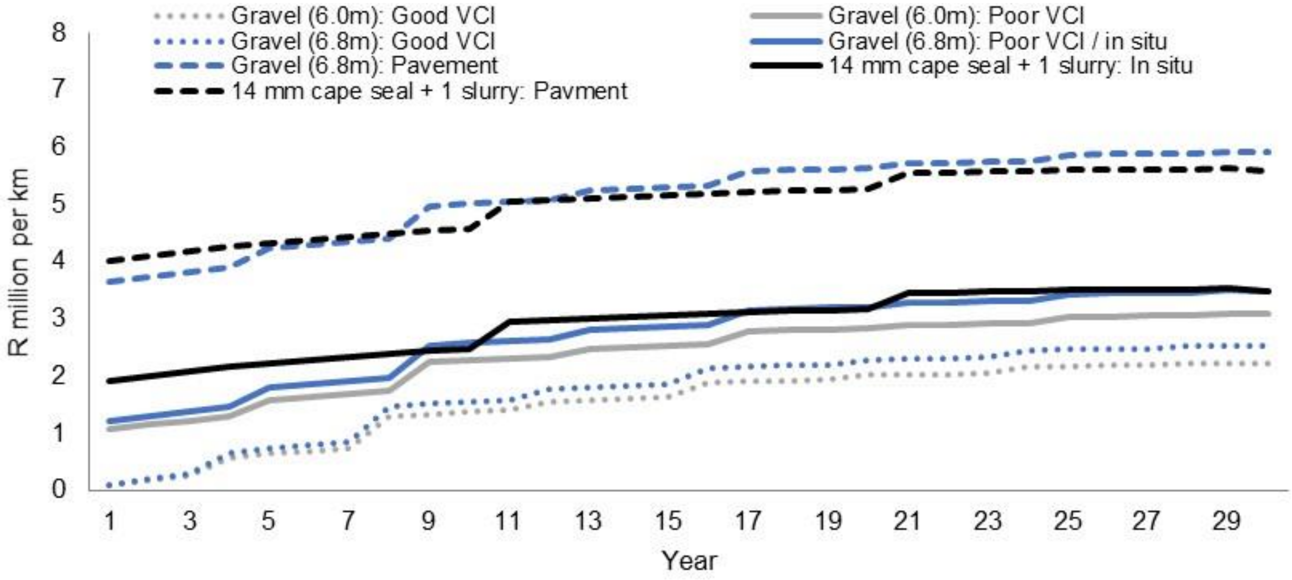
Figure 7.5: Effective average spacing between operating borrow pits, 2019



Source: Department of Mineral Resources, 2019.

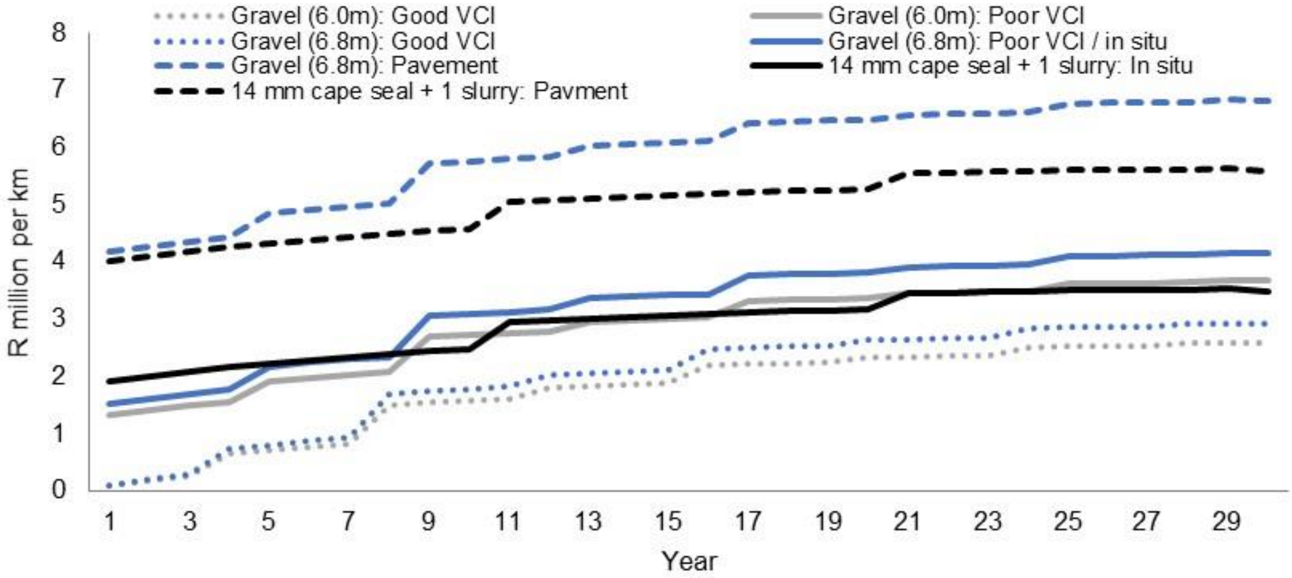
Every 1.0 km increase in the average haul distance increases the fuel input (*F*) in Equations 7.3 and 7.4 by 14.3%. Maintaining the baseline conditions, Figures 7.6 and 7.7 respectively illustrate the effect that extending the average gravel haul distance to 25.0 km and 50.0 km have on the relative cost-effectiveness of gravel roads. If the in situ subgrade is good then it is cost-effective to seal 6.8 m wide gravel roads in poor and very poor condition once the average haul distance is 25.0 km. However, when the average haul distance reaches 50.0 km it is cost-effective to seal both 6.0 m and 6.8 m wide gravel roads in poor and very poor condition. It is also cost-effective to seal new roads requiring a traditional pavement design once the average haul distance exceeds 17.0 km.

Figure 7.6: LCCA for 25.0 km average haul distance



Source: Own calculations.

Figure 7.7: LCCA for 50.0 km average haul distance



Source: Own calculations.

These findings confirm the strategies adopted by some road authorities. For example, the Western Cape Department of Transport and Public Works (2015) planned to review gravel roads separated from borrow pits for upgrade to surfaced standard, with 138.8 km of such roads identified for sealing in the Overberg District Municipality. The *2016 Strategic Borrow Pit Plan* for the West Coast District Municipality proposed that light bituminous seals be used to protect the base layer where roads are far from sources of suitable wearing course gravel (Western Cape Department of Transport and Public Works, 2016). Similarly, The Northern Cape Department of Roads and Public Works' (2017) RAMP states that: "Gravel suitable for road construction and maintenance is a diminishing resource and will accordingly have to be transported over increasing distances. This will inevitably result in surfacing becoming an economic alternative to regravelling as a maintenance process."

7.3.6 Increase in the price of oil-based inputs

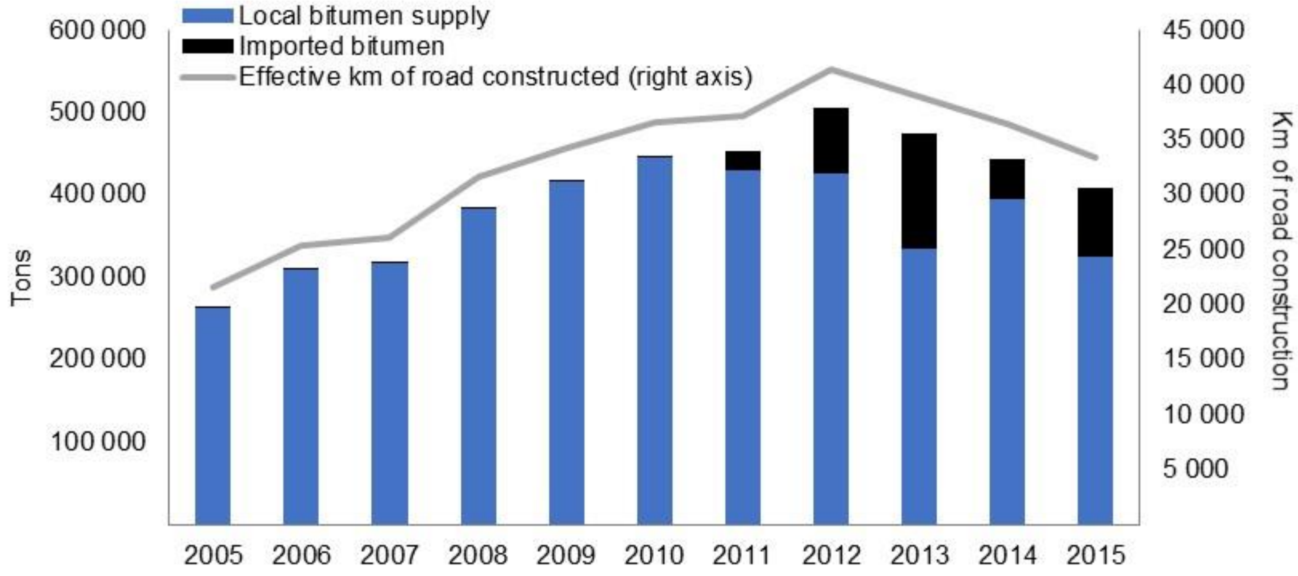
Bitumen and fuel are petroleum products and so their prices are driven by international oil prices and the exchange rate. Gravel is hauled to road sites by trucks running on petroleum fuel, typically diesel. But unlike expenditure on bitumen for sealed roads, which is required for construction and then in lesser quantities for resealing, gravel haulage and blading are recurrent costs due to the repeated need to shape the surface and replace lost gravel.

Because South Africa's petroleum is imported and fuel comprises a larger proportion of the future discounted maintenance costs for gravel than sealed roads, Ross and Field (2007) argue that fluctuations in the exchange-rate and oil price have a larger effect on the NPV of gravel than sealed roads. If the local fuel price continues to rise and the rand continues to depreciate against the USD, which occurred on aggregate between 2006 and 2019, then the cost-effectiveness of sealed roads is expected to improve relative to gravel roads.

Figure 7.8 illustrates the constrained bitumen supply in South Africa. The local bitumen price escalated in the mid-2000s, driven by changes in the world cost of petroleum products and supply issues caused by planned and unplanned shutdowns at South African oil refineries. Supply shortages in 2013 meant that 29.5% of the local bitumen consumption was covered through imports at an increased margin of 21.8% (Cokayne, 2013). Such fluctuations in the supply and price of bitumen caused cost overruns on sealed road projects through price adjustment clauses in contracts, as shown by the Gauteng Department of Public Transport, Roads and Works which attributed the bulk of a 67.0% year-on-year increase in 2005 in the cost to seal a low-volume gravel road to the higher bitumen prices (Ross and Field, 2007).

Approximately 5.5 million tonnes of bitumen are required to seal the entire proclaimed gravel road network, which is 17 times the 2015 local bitumen production. Although some gravel roads will not meet the criteria for being maintained, the local bitumen storage capacity and percentages of residual crude oil would need to increase to reduce the country's reliance on relatively expensive imported bitumen that would stress the cost to seal gravel roads.

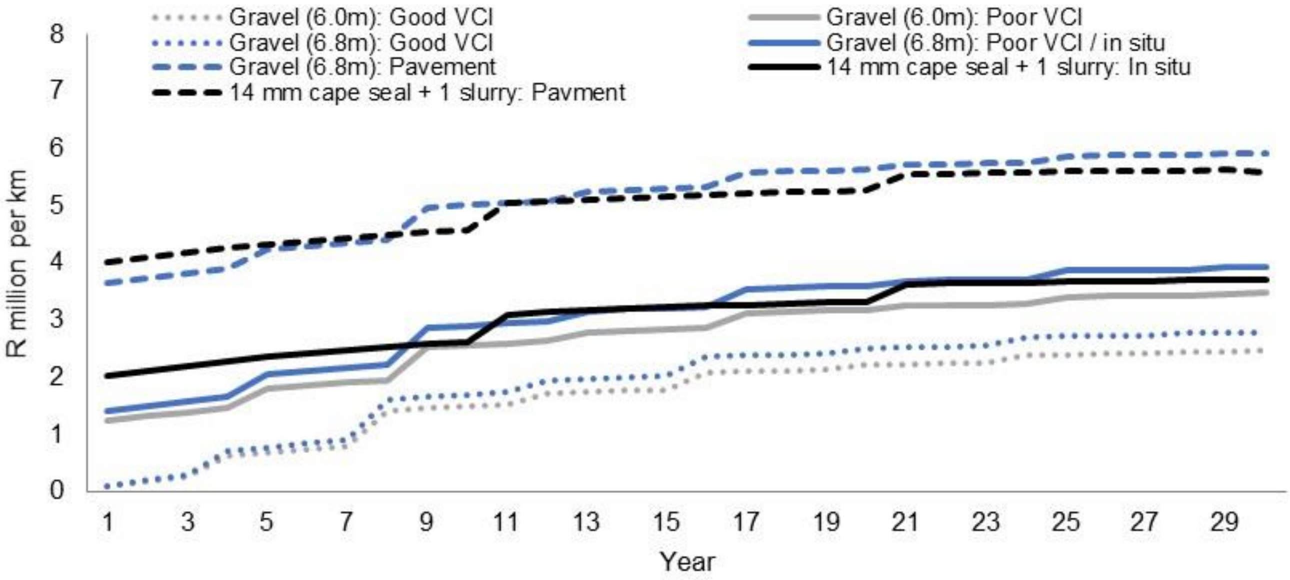
Figure 7.8: Bitumen consumption in South Africa, 2005-2015



Source: SABITA, 2018.

The argument that the proportional impact of rising oil prices on roadwork costs increases for gravel roads relative to bitumen roads as time horizons extend is tested in Figure 7.9. The LCCA is based on the baseline scenario except the average haul distance is extended to a more realistic 25.0 km and the price of fuel and bitumen, which are oil-based inputs, are inflated by 50.0%. When compared to Figure 7.6, in which only the change to haul distance applies, it is evident that a rise in the oil price supports the case to seal gravel roads. If the in situ subgrade is good it is cost-effective to seal 6.8 m wide gravel roads in poor condition, with the upgrade paid off by year 9. It is also cost-effective to seal new roads requiring a traditional pavement design.

Figure 7.9: LCCA for a 25.0 km gravel haul distance and 50.0% rise in the price of oil-based inputs



Source: Own calculations.

This stress test corresponds with the findings by Jahren *et al*. (2005) in South-East Asia and the following two conclusions drawn for South Africa by Ross and Field (2007): because a higher proportion of the cost of gravel roads than sealed roads is driven by petroleum prices, the relative opportunity costs of gravel and sealed roads shifts in favour of sealed roads as the local petroleum price increases; and the haul distance at which sealed roads become more cost-effective in terms of oil-price linked inputs than gravel roads will get smaller, at an accelerating rate, were the local oil price to rise. Despite being a petroleum-derived product, bitumen does not represent an intensive allocation of oil to roads relative to gravel surfaces.

7.3.7 Shadow price of labour

The Department of Public Works created the Expanded Public Works Programme (EPWP) to help absorb unemployed and discouraged work-seekers by utilising public expenditure to generate additional employment through labour-intensive work methods. This supports the National Development Plan (NDP) objective to expand public employment programmes to address the high unemployment rates across South Africa, particularly in rural areas where there is a large pool of underutilised unskilled labour (National Planning Commission, 2012). The Department of Public Works (2012) argues that within the infrastructure sector, which created the most EPWP jobs from 2004 to 2012, the highest employment creation potential lies in roadwork. The Construction Industry Development Board (CIDB) (2005) confirm the road sector is among the most efficient in generating employment opportunities.

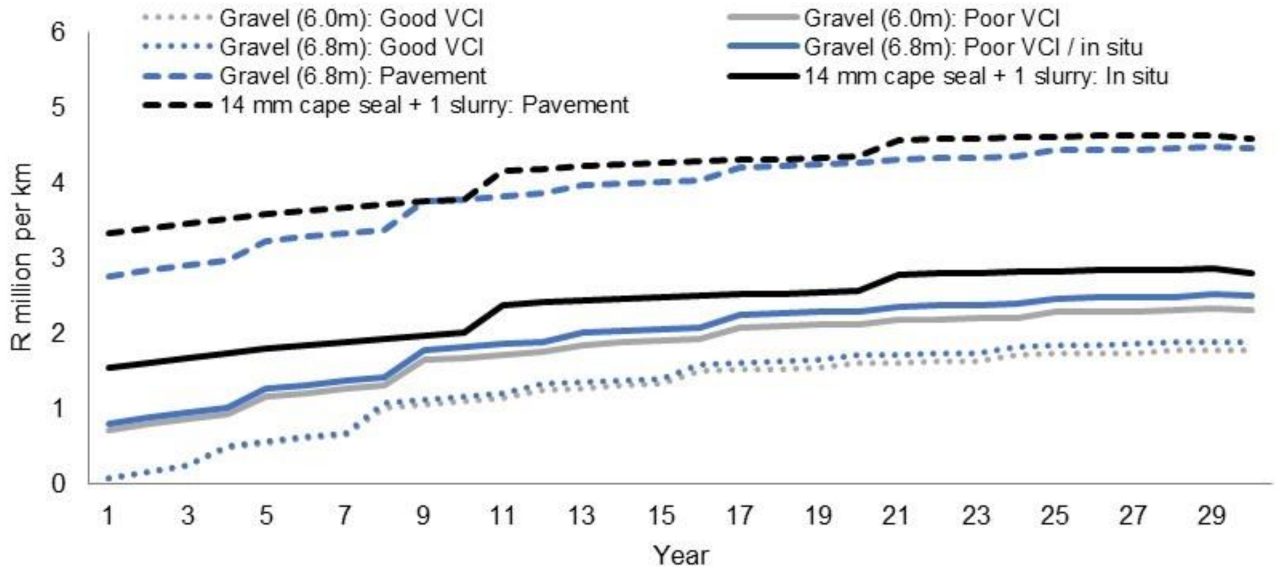
The following policy statements in the *2018 Draft Roads Policy for South Africa* support both the NDP and EPWP: “labour-intensive road construction and maintenance methods must be used wherever cost, time and quality are not compromised; employment-creation efforts within the roads sector must focus on the creation of multifaceted employment opportunities, including casual, temporary and permanent employment for semi and unskilled individuals; road projects must be used to provide short- to long-term employment to local unemployed people and to provide some form of training and skills development to equip people for the labour market; and projects on secondary and rural roads must support efforts to provide employment opportunities to rural communities, especially in marginalised areas” (National Department of Transport, 2018a). Preceding support was offered by the *1997 Green Paper on Public Sector Procurement Reform in South Africa*, which proclaimed that procurement should facilitate job creation in South Africa by: “ensuring that all foreign content in contracts involving goods, services and works is minimised; encouraging the substitution of labour for capital; and supporting the use of labour friendly technologies which utilise a higher degree of labour input than is the case for conventional technologies, or are well suited to implementation by small scale enterprises” (Department of Public Works, 1997).

Countries such as Kenya and Malawi increased the proportion of labour related road project costs to 38.0% (Hagen and Relf, 1988; Ngoma, 2003). But the provincial and municipal road authorities respectively achieved 13.0% and 9.0% in 2010/11 (Department of Public Works, 2012). To increase the proportion of labour in road project costs the Department of Public Works (2012) has called for wider application of programmes such as Zibambele and Sakha Sizwe, which appoint local households to conduct road maintenance using labour-intensive methods, and S’hamba Sonke. Adoption of an appropriate road surfacing policy that trades off capital for labour can enhance the ability of the sector to create lower-skilled employment opportunities. TRH 22 notes that apart from grader blading and haulage, most maintenance work on gravel roads can be effectively conducted using labour-based methods (Department of Transport, 2013). However, blading and haulage account for a high proportion of the cost to maintain gravel roads. Whereas construction and maintenance of gravel roads depends on heavy vehicles for grading and the long-distance haulage of materials, sealed roads can be built and maintained with light equipment that is suitable for labour-based methods and lower-skilled workers (Pinard and Overby, 2006).

TMH 20 also acknowledges that distortionary factors, such as the bargaining power of labour unions and minimum wage legislation, have led to discrepancies between the financial and economic price of unskilled labour in South Africa (Committee of Transport Officials, 2017). Ross and Field (2007) predict a large gap between formal sector market wages and shadow wages, particularly in rural areas, from the effect of an abundance of large, efficient farms on subsistence agriculture. Although it is sometimes the case that the cost to move an unemployed person from piecework and casual activity to formal employment is borne by members of that worker's household who invest more hours of farming to compensate for the difference, many under-employed workers in South Africa actually contribute less to household productivity than the share of the income they consume as a disproportionate share of the income for households with unemployed members is earned by grant recipients (Ross and Field, 2007; FHISHER, 2006; Bhorat *et al*., 2001). If such under-employed workers are transferred to the production of road infrastructure and their labour is at least as productive as an alternative unit of capital that could have alternatively been invested, Ross and Field (2007) argue that their shadow wage is zero or negative, or if their productivity in economic terms is not zero their shadow wage is zero. This potentially applies to many of the 5.6 million unemployed and discouraged worker-seekers that did not participate in any of the alternative productive activities to formal employment recorded by Statistics South Africa (2019) in 2018Q4.

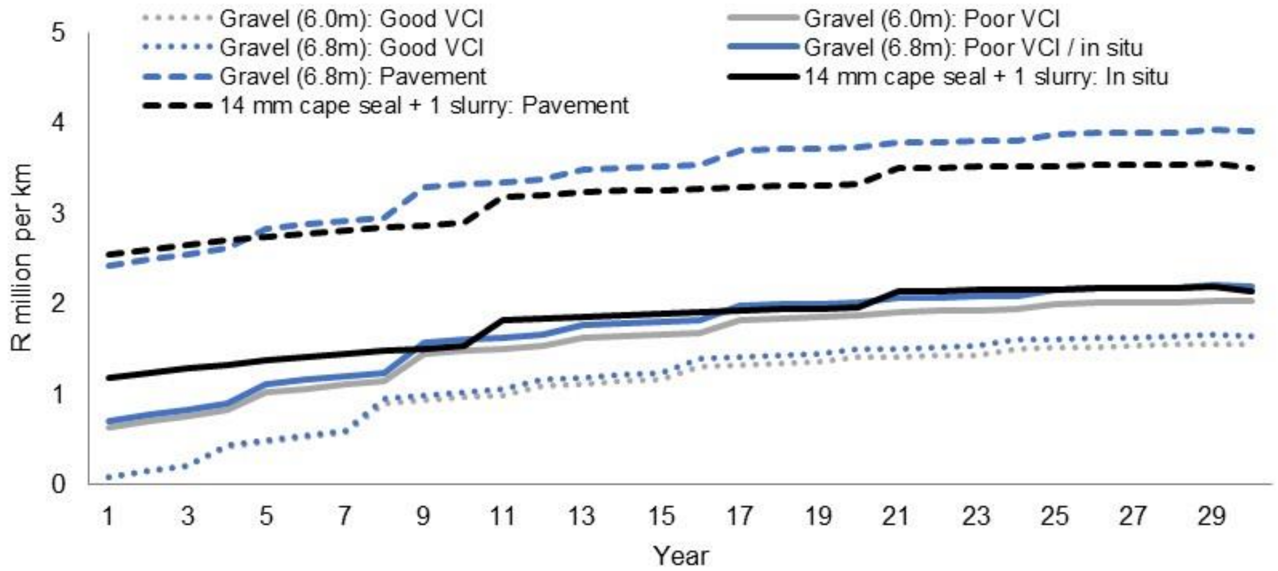
The stress tests in Figures 7.10 and 7.11 maintain the baseline conditions but change the proportion and price of unskilled labour utilised in road construction and maintenance works. The scenarios in Figures 7.10 and 7.11 assume the shadow price of rural unskilled labour is 0.5 of the market wage and zero, respectively, and that authorities increase the proportion of labour from 21.0% of road project costs in Equation 7.2 to 38.0%, as done by Kenya and Malawi. The CIDB's (2005) *Best Practice Guide to Labour-based Methods and Technologies for Employment Intensive Construction Works in South Africa* confirms the potential labour intensity for light bituminous seals should be approximately double that for gravel roads. If the road departments achieve this level of labour-intensity and the shadow price of labour is 0.5, the LCCA reflects the baseline finding that gravel roads are the cost-effective option. However, when the shadow price of labour is set at zero, which is likely the case in many rural regions, then the LCCA shows that it is cost-effective to seal 6.8 m wide gravel roads in poor and very poor condition wherever the in situ subgrade is good. If the shadow price of labour is zero, it is also cost-effective to seal new roads requiring a traditional pavement design. Gravel therefore becomes less attractive compared to light bituminous seals given South Africa's high unemployment rate and low levels of informal sector productivity.

Figure 7.10: LCCA applying labour-intensive work methods and 0.5 shadow price of labour



Source: Own calculations.

Figure 7.11: LCCA applying labour-intensive work methods and zero shadow price of labour



Source: Own calculations.

Ross and Field (2007) contend that for infrastructure investment decisions it is preferable to invest in labour as a government control variable rather than in a risk-free asset up until the difference between productivity per unit labour time multiplied by the market wage rate and productivity per unit labour time multiplied by the shadow wage rate is greater than the returns on the risk-free asset. Moreover, it is better to invest in labour-intensive sealed roads rather than gravel roads, even if the accounting cost is higher for the former, on account of two facts: the shadow wage rate for a high portion of rural workers in South Africa is zero or negative; and machinery is less efficiently used in rural than urban areas due to transport costs and reduced economies of scale (Ross and Field, 2007). This renders it sound public economics to subsidise some portion of this difference.

7.3.8 Road user costs

Gravel roads are susceptible to slipperiness in both wet and dry weather (Department of Transport, 2013). Caterpillar (2004) report that the coefficient of traction for rubber tyres, which is the ratio of the horizontal force that would cause tyres to move relative to the road surface to the vertical force on the tyre, is 0.36 on gravel and 0.90 on a paved road. Gravel also generates dust that reduces visibility for following and approaching vehicles. These two factors lead to a lower level of safety on gravel roads compared to surfaced roads.

SANRAL’s (2018) national HDM-4 configuration captures the higher accident rates on gravel than surfaced roads. Table 7.7 presents the average road accident rates applicable to earth, gravel, and the lowest class of surfaced roads. The Road Traffic Management Corporation (RTMC) (2016) lists the following human and vehicle accident costs for 2015: R5.4 million per fatal accident; R765 664 per accident resulting in serious injury; R152 244 per accident resulting in minor injury; and R48 533 per accident with vehicle damage only. Assuming an average cost of R458 954 for accidents resulting in serious and minor injuries, these data are used to estimate the total accident costs per 100 million vehicle-km travelled on each road surface. For every 100 million vehicle-km the accident costs on gravel roads are R73.7 million higher than for single carriage roads with a paved shoulder. The relatively low safety afforded by gravel roads thus represents a significant avoidable cost to property and life.

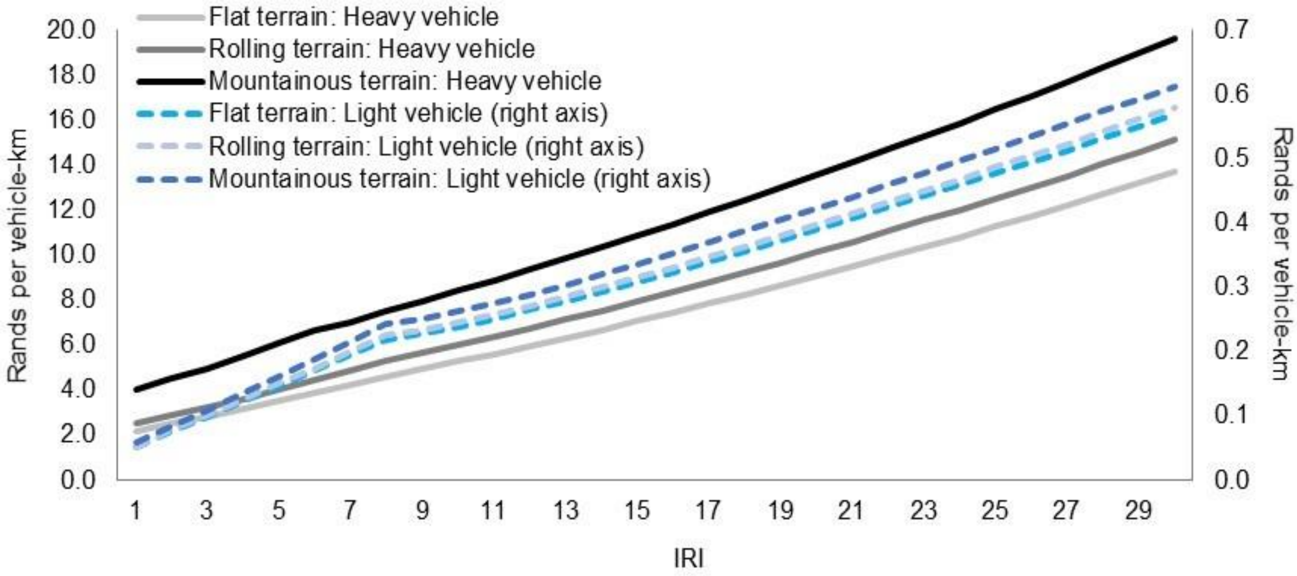
Table 7.7: HDM-4 accident classes and the associated costs, 2015

Road description	Accident rates per 100 million vehicle-km			Total accident costs per 100 million vehicle-km
	Fatal	Injury	Damage only	
Unpaved dirt road	13.9	141.7	988.2	R188 591 089
Engineered gravel road	12.1	122.9	857.4	R163 623 374
Single carriage with unpaved shoulder	6.9	70.7	492.8	R94 053 140
Single carriage with paved shoulder < 1 m	6.6	67.6	471.2	R89 932 255

Source: SANRAL, 2018b; Road Traffic Management Corporation, 2016a; Own calculations.

Because of the smoothness of the running surface the rolling resistance for a vehicle on a surfaced and gravel road is 1.5% and 10.0% of its weight, respectively (Caterpillar, 2004). Vehicles travelling on surfaced roads thus consume less fuel and sustain less wear and tear on the suspension system and tyres than vehicles travelling on gravel roads. Dust generated from gravel roads also contributes to greater wear on vehicles. Figure 7.12 demonstrates the additional vehicle operating costs (VOC) incurred on gravel compared to surfaced roads according to the road's International Roughness Index (IRI).

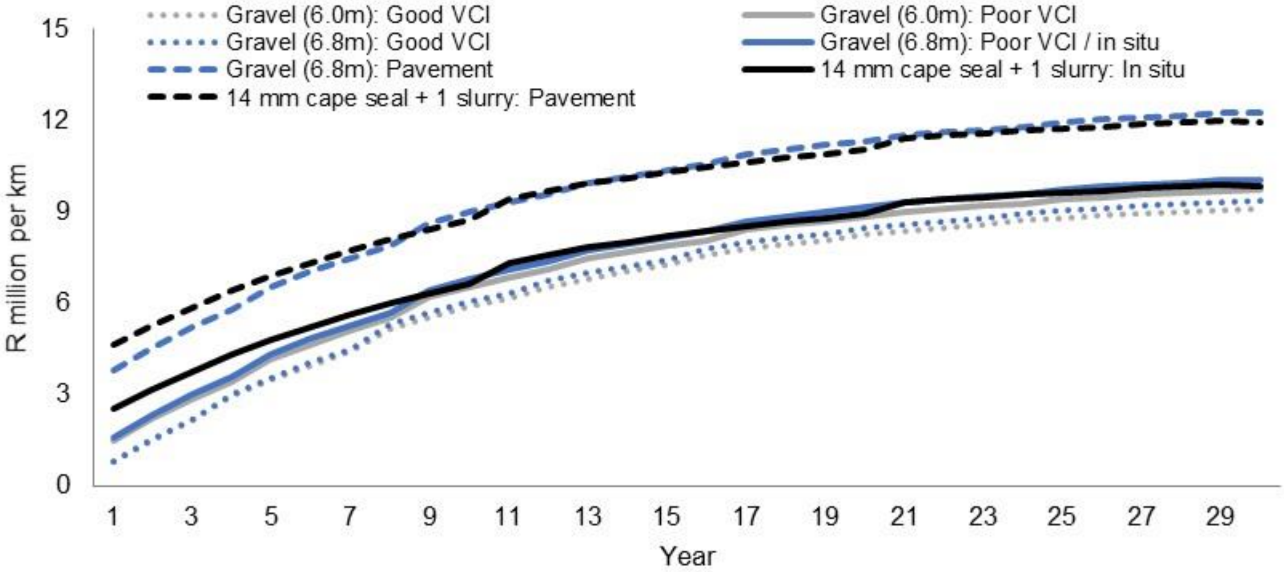
Figure 7.12: Vehicle operating costs on gravel roads versus surfaced roads



Source: Western Cape Department of Transport, 2018a.

The LCCA in Figure 7.13 adds road user costs (RUC) to the baseline scenario. The RUC reflect the road accident costs and VOC for 150 VPD, of which 20.0% are heavy vehicles. When RUC are included in the LCCA, it is cost-effective to seal 6.0 m and 6.8 m wide gravel roads in poor and very poor condition with good in situ subgrade. Authorities that took fully seriously these costs would therefore seal gravel roads at AADT as low as 150. At this traffic level it is also cheaper to seal new roads requiring a traditional pavement design.

Figure 7.13: LCCA including the VOC and road accident costs associated with 150 vehicles per day



Source: Own calculations.

7.3.9 Typical road conditions

The overwhelming majority of gravel roads in South Africa are subject to more than one of the stress test variables examined above. Table 7.8 presents the LCCA for combinations of variables that commonly affect the cost of low-volume roads. In terms of the variables: "RUC" adds VOC and road accident costs associated with 50 VPD; "haulage" extends average haul distance to 25.0 km; and "high gravel loss", "high moisture", and "steep gradient" use the specifications from the above stress tests. Under these combinations of conditions, it is cost-effective to seal 6.0 m and 6.8 m wide gravel roads in poor and very poor condition when the in situ subgrade is good, as well as new roads requiring a traditional pavement design. While it is cost-effective to maintain gravel roads in good condition under certain conditions, it is rare for gravel roads carrying only 50 VPD to have been kept in good condition.

Table 7.8: LCCA considering common combinations of the stress test variables at 50 VPD

	Lifecycle costs per km (R million)						
	Gravel					Cape seal	
	Poor VCI		Good VCI		Pavement	In situ	Pavement
Stress test combinations	6.0 m	6.8 m	6.0 m	6.8 m			
RUC + haulage	5.6	5.9	4.6	4.9	8.3	5.6	7.7
RUC + high gravel loss	6.1	6.5	5.6	6.0	8.7	5.6	7.7
RUC + high gravel loss + haulage	6.6	7.2	5.9	6.4	9.6	5.6	7.7
RUC + high moisture + haulage	6.6	7.2	5.6	6.0	11.5	6.1	9.9
RUC + steep gradient + haulage	7.0	7.6	5.8	6.3	11.7	6.3	9.9

Source: Own calculations.

Table 7.9 repeats the LCCA in Table 7.8, except traffic is increased to 150 VPD. Many good condition gravel roads are within this, or a higher, AADT category. Under these conditions the only situation where gravel roads should be maintained as such is when only RUC and haulage are considered for 6.0 m wide gravel roads in good condition. Otherwise, the stress test combinations indicate that it is cost-effective to seal 6.0 m and 6.8 m wide gravel roads in good and poor condition wherever the in situ subgrade is good. All scenarios demonstrate that it is cost-effective to seal new roads requiring a traditional pavement design.

Table 7.9: LCCA considering common combinations of the stress test variables at 150 VPD

	Lifecycle costs per km (R million)						
	Gravel					Cape seal	
	Poor VCI		Good VCI		Pavement	In situ	Pavement
Stress test combinations	6.0 m	6.8 m	6.0 m	6.8 m			
RUC + haulage	10.3	10.7	9.5	9.8	13.1	9.8	11.9
RUC + high gravel loss	10.9	11.4	10.4	10.8	13.6	9.8	11.9
RUC + high gravel loss + haulage	11.5	12.0	10.8	11.2	14.5	9.8	11.9
RUC + high moisture + haulage	11.4	12.0	10.4	10.9	16.3	10.3	14.1
RUC + steep gradient + haulage	11.8	12.4	10.7	11.1	16.5	10.5	14.1

Source: Own calculations.

7.4 ADDITIONAL COST FACTORS

7.4.1 Dust

Dust can travel hundreds of metres from a gravel road and is released from the surface under the wheels of moving vehicles, the turbulence caused by vehicles, and through wind. All gravel roads abrade to some extent to produce dust, but well-designed gravel roads constructed and maintained with good quality materials generate less dust (Greening, 2011). Other determinants of the dustiness of a gravel road include the: AADT; mix and speed of vehicles; looseness of materials; moisture content of the road; and maintenance frequency (Department of Transport, 1990).

Jones (2000) adapted Equation 7.5, which is from the Environmental Protection Agency's AP-42 dust prediction model, to Equation 7.6 to estimate that South Africa's unpaved road network generates 3 million tonnes of dust per annum. The Department of Transport revised this figure to 4 million tonnes per annum to account for the increase in proclaimed unpaved roads and higher average vehicle speeds and weight (Greening, 2011).

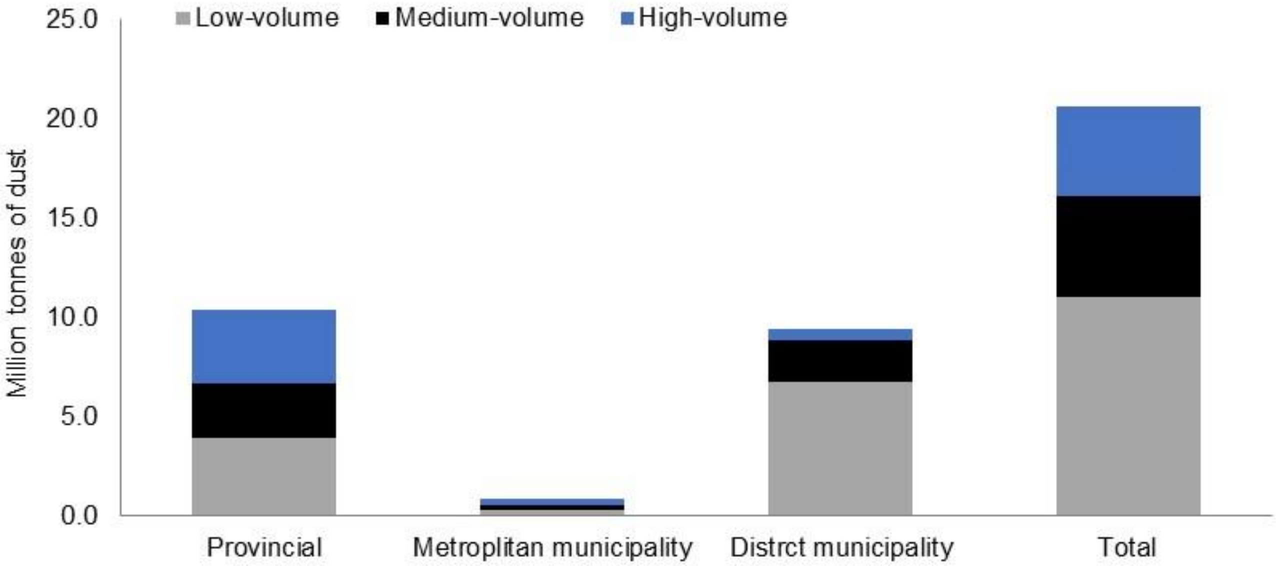
$$E = k(\frac{s}{12})(\frac{S}{48})(\frac{W}{2.7})^{0.7}(\frac{w}{4})^{0.5}(\frac{365-p}{365}) \qquad 7.5$$

$$E = 0.8(\frac{15}{12})(\frac{60}{48})(\frac{1.5}{2.7})^{0.7}(\frac{4}{4})^{0.5}\left(\frac{365-130}{365}\right) = 0.534 \text{ kg/vehicle km} \qquad 7.6$$

where *E* is the emission factor in kg/vehicle-km, *k* is the particle size multiplier, *s* is the silt content (<0.075 mm) of surface material (%), *S* is the average vehicle speed (km/h), *W* is the average vehicle weight (tonnes), *w* is the average number of wheels, and *p* is the mean annual days with rainfall greater than 0.25 mm.

Figure 7.14 shows the estimated dust emissions from the unpaved road networks in 2017 using Equation 4. The estimate is based on the AADT data from Chapter 4, in which AADT on 84.0%, 8.0%, and 8.0% of provincial and metropolitan municipality unsealed roads are respectively between 0 and 249, 250 and 499, and more than 500 vehicles. AADT on 95.4%, 3.8%, and 0.8% of district municipality unsealed roads is between 0 and 249, 250 and 499, and greater than 500 vehicles. Average AADT is assumed to be 50 for roads with AADT between 0 and 249, 375 for roads with AADT between 250 and 499, and 500 for roads with AADT above 500. The results indicate that about 20.6 million tonnes of dust were generated from the proclaimed unsealed road network in 2017. Jones (2000) notes that two-thirds of this dust will settle back onto the road. The provincial, metropolitan municipality, and district municipality unsealed roads respectively account for 10.4, 0.9, and 9.4 million tonnes of dust. Although high-volume gravel roads account for 3.8% of all proclaimed unsealed roads, this category accounts for 22.2% of total dust. The finding is a strong motivation to prioritise sealing the 17 275 km of high-volume gravel roads.

Figure 7.14: Dust generated from proclaimed unsealed roads, 2017



Source: Own calculations.

3 factors help explain the difference between this updated 2017 estimate and the study by Jones (2000). Firstly, the provincial and municipal gravel road networks have been revised upwards by 23 732 km and 80 877 km, respectively. Secondly, there has been 17-years of traffic growth. And lastly, detailed AADT data are now available. Jones (2000) acknowledged that comprehensive traffic data for unsealed roads was unavailable at the time of his study, which yielded a conservative dust generation estimate that was 3 times lower per vehicle-km than a similar study by the United States Forest Service (1973).

Dust generated from gravel roads has a variety of potential negative effects on the health of road users, pedestrians, and adjacent communities. The largest effect is on the respiratory system, with 10.0 μm and 2.5 μm particles small enough to pass through the nose and throat and enter the lungs (Greening, 2011). Certain gravels also contain undesirable materials such as asbestos and silica (Department of Transport, 2013). Annegarn and Kneen (1995) link dust generated by unsealed roads to 16.0% of airborne particle matter in communities in South Africa and higher incidences of respiratory disease, especially among children.

Dust generated from gravel roads has further negative effects on agricultural yields. Among other effects, dust coatings on crop foliage: reduce spray contact of pesticides, fungicides, and fertilisers; hinder pollination; reduce the efficacy of the transpiration and photosynthesis process; and cause leaf and fruit scorch and discolouration (Jones, 2000). These effects reduce agricultural yields and prices. A study by HKS (1992) in the Western Cape Province found trees in fruit orchards adjacent to unsealed roads to be smaller and less productive than trees further from the roads, with 80.0% to 100.0% of trees in the three rows closest to the road smaller than the orchard average. Tree and leaf size improved with distance from an unsealed road until the eighth row, from which there were no longer negative effects from dust. Additional applications of insecticide spray were required on trees adjacent to unsealed roads to counter higher insect activity, with the associated increase in chemical costs listed at R1 500 to R2 200 per km in 1992. In terms of livestock, a study by McCrea (1984) in New Zealand found that dust from unsealed roads reduced lambing rates by 1.0% and milkfat yields due to a reluctance by livestock to eat dust contaminated pasture. Greening's (2011) international literature review concluded that dust from gravel roads reduced crop values by 1.0% to 5.0%.

Agencies such as the CSIR (2003), Virginia Transportation Research Council (Bushman *et al.*, 2004), and Tanzanian Roads Authority (2016) criticise the effectiveness and affordability of dust palliatives to limit dust emissions. It is therefore important that the relevant data are collected to factor dust-related health and agricultural costs into future versions of the LCCA.

7.4.2 <u>Biodiversity</u>

The CSIR (1993) advocate surfacing gravel roads in sensitive environmental areas, notably the 6.0% of South Africa's surface area classified as formally protected biodiversity zones (UNDP, 2001). TRH 20 notes that gravel roads have greater negative environmental effects than sealed roads (Department of Transport, 2013). Whereas borrow pits can be closed and rehabilitated following construction of sealed roads, the repeated reworking of borrow pits needed by gravel roads does not allow these areas to be rehabilitated in the short to medium term (CSIR, 1993). Dust from gravel roads also harms surrounding flora, especially in hilly areas that experience winter temperature inversions. However, sealed roads facilitate faster vehicle speeds that increase the incidence of roadkill. Data limitations precluded biodiversity costs from the LCCA, but future research should seek to incorporate this factor.

7.4.3 Water

The construction and maintenance of gravel roads requires large volumes of water. Although dry compaction of gravel is possible, the CIDB (2007) and TRH 20 advise against it in South Africa (Department of Transport, 2013). The CIDB (2007) prescribe 150 to 170 litres of water per m^3 of gravel for compaction. If the average gravel loss across the proclaimed gravel road network is 10 mm per annum, then 4.6 million m^3 of water, which roughly equates to 0.5% of the capacity of the Vaal Dam, are needed annually for regravelling. Although rainfall eases water requirements, many parts of the country where gravel roads are prevalent are water scarce and experience long dry seasons. For example, the Western Cape Department of Transport and Public Works (2017) highlight that the availability of water for compaction is expected to decline due to climate change. Once suitable data are available the LCCA must be extended to address water costs, which are expected to motivate sealing gravel roads. In fact, the International Bank for Reconstruction and Development (2018) warn against the use of gravel roads in India over concerns regarding the water intensity of this road surface.

7.5 WELFARE BENEFITS OF A POLICY TO SEAL LOW-VOLUME ROADS

In addition to allowing road authorities to accommodate more kms of road with the available maintenance budgets, which means the road network can support higher levels of economic activity, a policy to seal gravel roads creates further welfare benefits. Following from Section 7.3.7, sealing gravel roads is an effective mechanism to absorb and upskill unskilled workers with very low, if not almost zero opportunity cost. This change to the current pattern of labour utilisation would help reorient the roads sector from capital- to labour-intensive capacity and thereby help build a more balanced capital spread across the country.

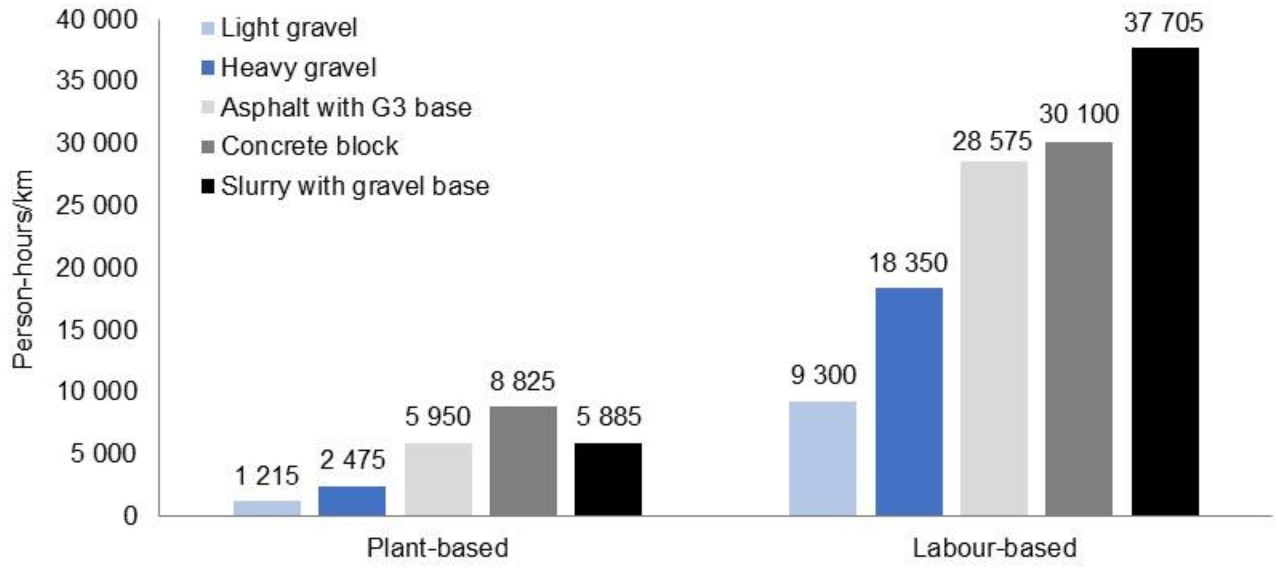
7.5.1 Employment opportunities

The most significant employment benefits from sealing gravel roads are generated through the on-going routine and periodic maintenance events. This extends the impacts of a policy of sealing gravel roads from temporary to long-term employment. Some periodic and routine maintenance activities are similar across road surfaces, such as brush and weed control – although even these activities utilise more labour on sealed roads to improve sight distance given the higher vehicle operating speeds. A high proportion of gravel road maintenance is performed using heavy, capital equipment - such as motor graders, compactors, and water and haul trucks - that often cannot be feasibly substituted for labour. However, the capital equipment used to maintain light bituminous seals support labour-intensive practices. TRH 3 lists the following basic plant and equipment requirements for cape seals: stand for 210 litre drum and steel ramps; 250/175 litre concrete mixer; small spreader box; templates/steel rails; shovels; steel and rubber squeegees; wheelbarrows; measuring containers; string line; hessian; motorised hand sprayer; pedestrian roller; screens; measuring containers to spot the aggregate; and wide brooms (SANRAL, 2007). In addition, sealed road maintenance includes additional labour-based activities beyond gravel roads, such as road markings.

This maintenance dynamic over time is the primary motivation from a labour perspective for a policy to seal gravel roads worth maintaining. Unfortunately, there are insufficient data to estimate the maintenance-related employment benefits from sealing gravel roads. However, the CIDB (2005) guidelines cover the potential labour intensity of different road construction and rehabilitation works and even this partial analysis provides a compelling motivation for sealing gravel roads.

The impact that road pavement and surface type have on the person hours generated from road construction is presented in Figure 7.15. Roads surfaced with asphalt, concrete, or slurry using plant-based methods respectively generate 489%, 726%, and 484% additional employment opportunities per km than the alternative of a light gravel road. If labour-based methods are utilised, then construction of an asphalt, concrete, or slurry road respectively creates as much as 307%, 324%, and 405% extra employment opportunities per km of road than a light gravel road.

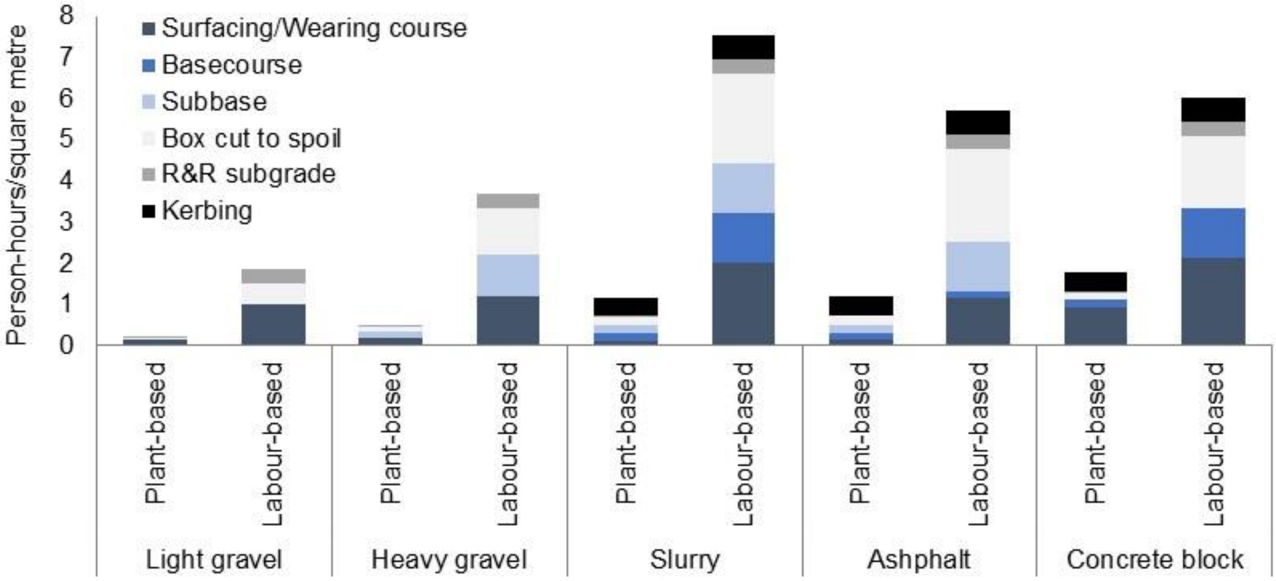
Figure 7.15:Person-hours required to construct a 5.0 m wide low-volume road in South Africa



Source: Department of Public Works, 2002; Construction Industry Development Board, 2005.

The disaggregated person-hours shown in Figure 7.16 explain the difference in employment potential between the road pavement and surface alternatives. The person-hours are based on the sum of the following labour requirements: manufacture precast concrete products in a factory (plant-based) or on-site (labour-based); obtain materials in quarrying operations; transport materials or precast concrete products an average of 20.0 km to the site; and build the layers and items (CIDB, 2005). The person-hours for labour-based construction of slurry, asphalt, and concrete surfaced roads are respectively 201.1%, 117.0%, and 212.0% higher than for a light gravel wearing course. Upgrading gravel roads to a surfaced standard can also generate extra person-hours compared to gravel road maintenance through the works associated with the basecourse, subbase, and kerbing. Based on the person-hours required to construct the gravel wearing course, a policy to seal light gravel roads with slurry rather than undertake regravelling could generate an additional 15.6 full-time equivalent (FTE) jobs per km. The actual number of FTE jobs created would typically exceed this figure as many gravel roads are between 6.0 and 6.8 m wide, however, the following analysis is based on the CIDB's published estimate of 15.6 additional FTE jobs per km of gravel road sealed.

Figure 7.16: Person-hours associated with layerworks and kerbing for a 5m wide low-volume road



Source: Department of Public Works, 2002; Construction Industry Development Board, 2005.

Table 7.10 details the length and condition of the proclaimed provincial and municipal gravel road networks in 2017. The bulk of potential employment creation from sealing gravel roads lies with the municipal gravel road network, which is 61.7% longer than the provincial gravel road network. 352 301 km of gravel roads in the combined networks were in poor and very poor condition compared to 31 319 km in good and very good condition. Roadwork activities would thus extend to 77.5% of the combined gravel road networks should authorities begin by sealing gravel roads that alternatively require extensive regravelling.

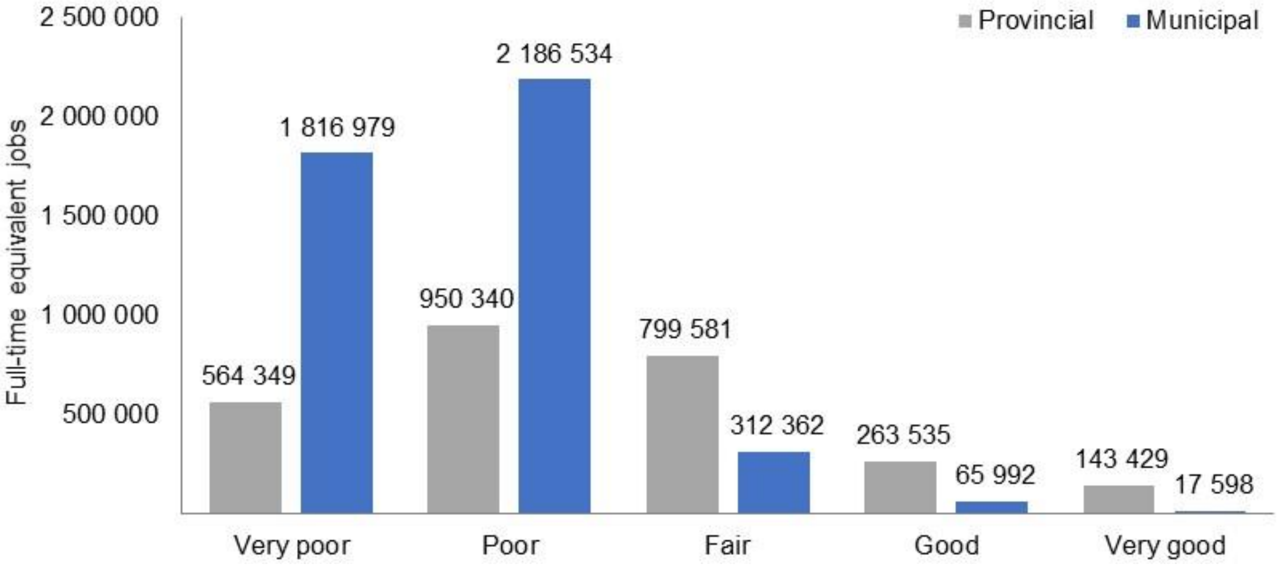
Table 7.10: Condition of provincial and municipal gravel road networks, 2017

Authority	Road condition (VCI)				
	Very poor	**Poor**	**Fair**	**Good**	**Very good**
Provincial	36 030	60 673	51 048	16 825	9 157
Municipal	116 002	139 596	19 942	4 213	1 124
Total	**152 032**	**200 269**	**70 990**	**21 038**	**10 281**

Source: National Treasury, 2018a.

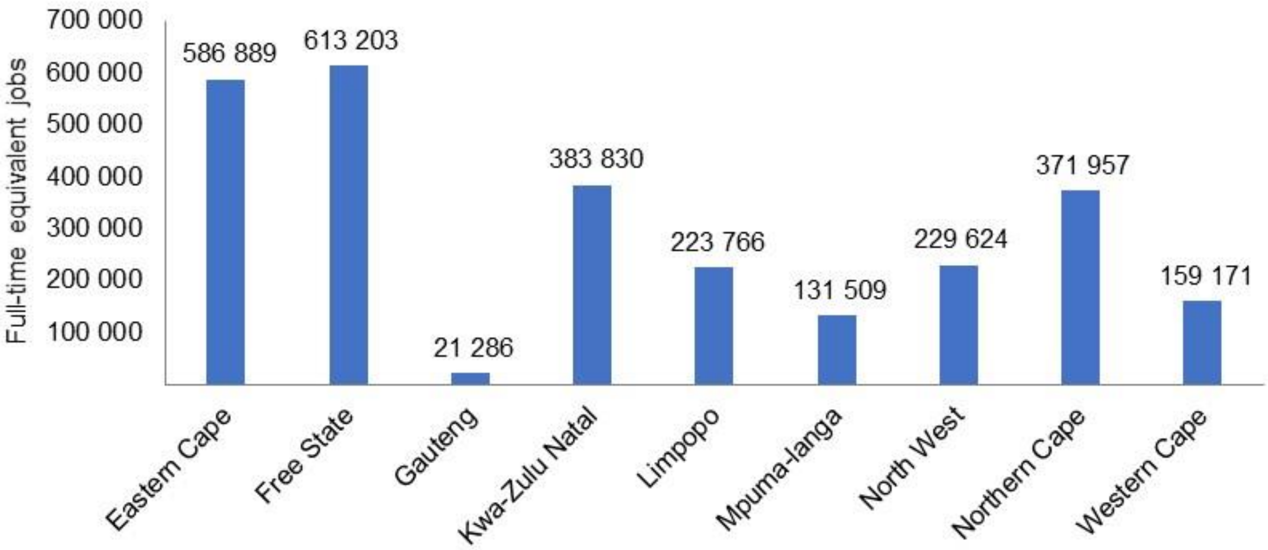
The approximate number of potential FTE jobs from a policy to seal all gravel roads is shown in Figure 7.17. This estimate was calculated by applying the 15.6 additional FTE jobs created per km of gravel road sealed to the network details in Table 7.10. However, it is important to reiterate that some gravel roads will not meet the criteria set in Chapter 6 for maintenance. A policy to seal gravel roads with a light bituminous seal could generate around 7.1 million additional FTE jobs across all proclaimed gravel roads, with the provincial and municipal networks respectively comprising 38.2% and 61.8% of the total FTE jobs. Sealing just the gravel roads in poor and very poor condition creates 5.5 million additional FTE jobs.

Figure 7.17: Additional FTE job opportunities from sealing gravel roads by road condition



Source: Own calculations.

Figure 7.18: Additional FTE job opportunities from sealing provincial gravel road networks

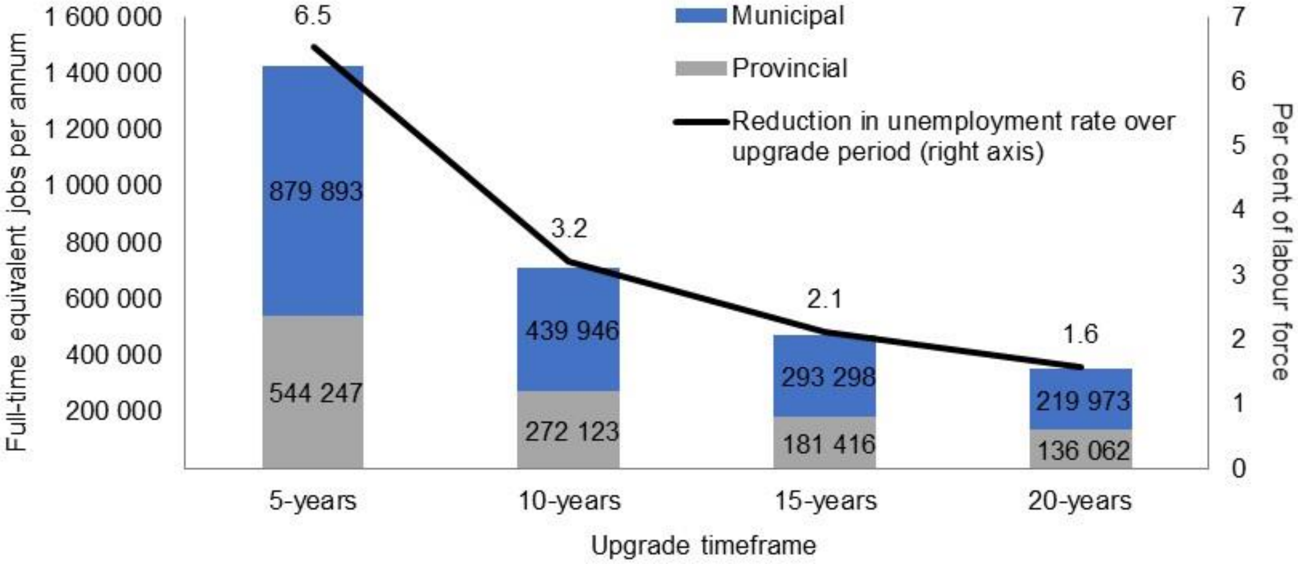


Source: Own calculations.

Figure 7.18 shows the additional FTE jobs opportunities from sealing provincial gravel roads. The highest number of additional FTE jobs can be generated by sealing the provincial gravel roads in the Free State and Eastern Cape, which respectively had expanded unemployment rates of 41.1% and 53.0% outside the metropolitan areas in 2018Q4 (Statistics South Africa, 2019). Sealing the provincial gravel road network in Gauteng offers the lowest number of additional FTE jobs due to the relatively short length of this network.

Figure 7.19 equally apportions the total FTE job opportunities across years according to possible timeframes over which road authorities may seal gravel roads. The scenarios cover sealing provincial and municipal gravel roads over 5-, 10-, 15-, and 20-year periods starting in 2020. The longer term scenarios are more realistic given the magnitude of the required work, current capacity constraints within the construction sector, and the limited domestic bitumen supply. The average annual reduction in the unemployment rate over each sealing timeframe was estimated based on long-term population estimates by the Actuarial Society of South Africa and the 2018Q4 labour force participation rate of 59.4% (Statistics South Africa, 2019). The results indicate that sealing all proclaimed gravel roads over a 15-year period could generate approximately 474 713 additional FTE jobs per annum and reduce the national unemployment rate by 2.1% over the period. Alternatively, adopting a 20-year upgrade period could generate approximately 356 035 additional FTE jobs per annum and reduce the national unemployment rate by 1.6% over the period. In the context of a 27.1% unemployment rate in 2018Q4, both of the longer-term timeframes would make a significant contribution to lowering unemployment.

Figure 7.19: Annualised additional FTE job opportunities from sealing gravel roads at different rates



Source: Own calculations.

7.5.2 Substitution of inefficient welfare transfers for productive labour

The South African social welfare system does not include an automatic stabiliser to properly account for the high unemployment rate described in Section 7.3.7, such as a basic income grant. Taylor (2002) explains that the social welfare system was developed prior to formal acknowledgement of South Africa's structural unemployment challenge, at which time it was assumed that unemployed people can support themselves and unemployment is temporary. The Unemployment Insurance Fund (UIF) does support unemployed workers, but it provides limited support to only a small proportion of the unemployed as many of these people have not been in formal employment and thus are not registered with the UIF (Taylor, 2002). The result is that many unemployed workers are supported by households through other fiscal transfers, notably the state old age grant (Klasen and Woolard, 2014). Neves *et al.* (2009) confirm that the state old age grant is associated with larger household size, with many poor rural households formed around a recipient pensioner with the grant attracting unemployed family members into the household.

As a result of these inefficiencies within the redistributive social welfare system, a policy to seal gravel roads must not be viewed simply as a labour creation scheme. The unemployed workers absorbed through a policy to seal gravel roads would lower the state's social welfare burden at the same as developing productive road infrastructure. This tradeoff of inefficient, indirect transfers to unemployed workers for asset creation is therefore not a rand-for-rand swap. Rather, sealing gravel roads could generate large macroeconomic efficiency gains – perhaps in the order of 0.2 to 0.4 - which stands as a point of clarification for further research.

7.5.3 Substitution of local resources for imports

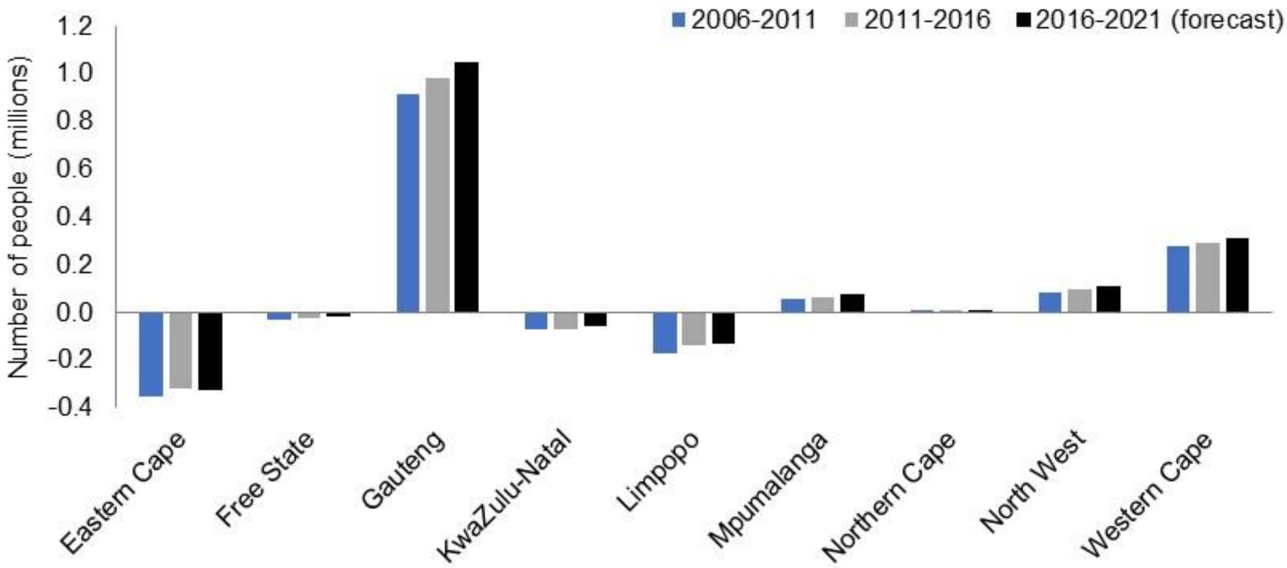
Petts (2002) contends that the imported, heavy equipment used to construct and maintain gravel roads are suited to countries with high-wage, low-investment-cost environments. The cost of imported capital equipment tends to be more expensive when interest rates are high and the exchange rate is volatile, conditions which both apply structurally in South Africa. In fact, between 2006 and 2018 the annual prime lending rate averaged 11.6% and the ZAR-US Dollar exchange rate depreciated by 131.3% (First National Bank, 2019; South African

Reserve Bank, 2018). Under these conditions the CIDB (2005) supports the substitution of labour for capital and local resources for imports.

7.5.4 Reduced short-term rural-urban migration pressures

Inadequate rural incomes and few job opportunities are among the factors that have forced people to relocate from rural areas to settle in urban centres or along transport corridors (National Planning Commission, 2012). Figure 7.20 shows the high rates of migration from the mostly rural Eastern Cape, KwaZulu-Natal, and Limpopo provinces to the more urban provinces of Gauteng and the Western Cape. Between 2001 and 2011 the urban population grew from 57.0% to 63.0% of the population (Statistics South Africa, 2011). Based on current migration rates the United Nations (2010) estimates that South Africa's urban population will grow to 71.3% by 2030 and 80.0% by 2050.

Figure 7.20: Net migration



Source: Statistics South Africa, 2018e.

The Brookings Institution (2016a) warn that rapid urbanisation could worsen infrastructure and service delivery challenges in urban areas. This seems true for South Africa, where the high migration rates in Figure 7.19 have contributed to traffic congestion and infrastructure backlogs in metropoles and secondary cities. The urban waste collection, water, sanitation, and electricity infrastructure backlog was estimated at R80.0 billion by the *2018 Integrated Urban Development Framework* (Department of Cooperative Governance and Traditional

Affairs, 2018). Further short-term growth in the urban population from rural-urban migration would exacerbate these backlogs.

Given the pressures associated with rapid urbanisation, The Brookings Institution (2016b) review the applicability of standard urbanisation models to the African context. Amongst the main conclusions, which is mirrored by Christiaensen *et al.'s* (2013) panel review of 51 low- and middle-income countries and Tanzanian case study, is that rural poverty alleviation is often best facilitated by the movement of rural workers to the rural non-farm economy or to nearby smaller secondary towns, rather than through urbanisation concentrated in cities. A policy to seal gravel roads could generate significant rural non-farm employment as well as promote rural diversification, which renders it an important tool to help create more balanced growth and thereby address the prevailing structural tendency for human capital to migrate to metropoles, especially Johannesburg and Cape Town, and slow rural-urban migration to a rate commensurate with urban infrastructure development. In this regard, a policy to seal gravel roads reflects the NDP objectives to: increase the rural employment rate from 29.0% to 40.0%; promote rural infrastructure investment that incentivises citizens to remain in rural areas; and ensure that citizens in rural areas are not locked into poverty (National Planning Commission, 2012).

Ross and Field (2007) raise the possible objection that the high urbanisation rate in South Africa lowers the priority of a programme focused on rural populations. However, in line with the Harris-Todaro model the high rural-urban migration rates suggest that the apparent gap between the legal minimum wage and market-clearing urban wage is at least partially driven by potential migrants racing one another for better-paying urban jobs, thereby lifting urban labour supply above the market's capacity to absorb the flow (Boardman *et al.*, 2018). Under such circumstances, because a policy to seal roads promotes the welfare of workers in rural areas it might also indirectly benefit workers in urban areas by disincentivising the former from joining the race in the short term.

7.5.5 Supply side infrastructure and human capital development

Gravel roads typically preclude local communities, small enterprises, and poor citizens from having an ownership stake in roadworks because of the high cost of capital and the large capital investment requirements in terms of specialist equipment to construct and maintain gravel roads. Petts (2002) argues that haulage and gravelling by tractors and trailers involve high equipment provision and operation costs. Compared to light bituminous seals, for which the capital investment is significantly lower and much of the required equipment is available for hire on the local market. This indicates the potentially high multiplier effect of a policy to seal gravel roads through the development of project management services and supply side infrastructure markets.

The provision of gravel roads is more susceptible than light bituminous seals to domination by relatively few large contractors (Petts, 2002). The inclusion of small contractors in road construction and maintenance works enhances human capital in the form of management, tendering, investment skills, and on-the-job training. The sector has developed programmes, for which sealed roads offer more learnership opportunities than gravel roads, to incentivise labour-intensive works on low-volume roads and grow capacity among emerging contractors (Department of Public Works, 2018). For example, the Vuk'uphile Learnership Programme trains contractors on labour-intensive work methods for routine road maintenance of class 4 and 5 roads. The Gauteng Department of Roads and Transport (2017) demonstrates the contractor development benefits of labour-intensive roadworks. The 29 learner contractors in Gauteng that were appointed in 2013 at CIDB grading levels one and two, meaning they only operated at local level, were exiting the programme in 2017 as level four and five contractors able to operate at a regional or provincial level. Such programmes present authorities with a mechanism to deepen the pool of human capital in the sector and thereby enhance the competitiveness of the procurement environment, which was among the concerns that prompted the National Treasury's (2018a) Government Technical Advisory Centre to undertake a performance and expenditure review of provincial road projects. The development of surfaced roads related human capital among emerging contractors may be even more important given the decision by SANRAL (2018), which only manages surfaced roads, to reserve certain projects for black-owned contractors.

Ross and Field (2007) argue that because human capital is a national economic asset with future multipliers it is important to appropriately set our willingness to invest in job creation within the sector (Ross and Field, 2007). Although human capital development improves the productivity of both individual contracting firms and potential national productivity, Ross and Field (2007) contend that the private sector is not incentivised to fund this national premium.

The onus is thus on the government to support and subsidise labour-intensive production. Consideration for human capital development does not affect the price of gravel roads, but rather raises the opportunity cost of gravel as alternative surfaces are more labour-intensive. The positive externalities associated with the labour-intensive work methods applicable to sealed roads shorten the break-even point for such roads.

7.5.6 All-weather road access to basic services

TRH 20 explains that passability on a road is a function of the shear strength or cohesion in the top layer of the wearing course (Department of Transport, 1990; 2013). Once the tractive stresses exerted by rotating wheels exceed the shear strength of the surface material then shearing results and vehicles are unable to proceed normally. Repeated shearing leads to churning of clayey materials and the affected section of road becoming impassable. Roads surfaced with sandy materials can also become impassable due to a rapid loss of vehicle traction at the surface, especially on steeper grades.

A primary objective of a gravel wearing course is to provide an all-weather surface, but this objective is often compromised in wet weather if the in-situ materials have a low bearing capacity and shear strength (Department of Transport, 2013). Design manuals for Ethiopia and South Sudan warn that access using gravel roads may be limited or prevented during rains, when streams and rivers flow, or if saturation and ponding occur (Ethiopian Roads Authority, 2016; Ministry of Roads and Bridges, 2013). TRH 20 references local experience to confirm a soaked California Bearing Ratio of 15.0% at 95.0% Mod AASHTO compaction is adequate to prevent well-shaped gravel roads from being excessively churned up, except in areas with extended periods of wet weather and excessive heavy traffic or if the surface drainage is inadequate (National Department of Transport, 1990; 2013).

However, the all-weather accessibility of gravel roads in South Africa is negatively affected by the Guidelines for Levels of Serviceability shown in Table 7.11 (Department of Transport, 2013). On account of resource constraints, it is proposed in TRH 20 that road maintenance requirements be matched to the required level of service, with low levels of service assigned to low-volume unsealed roads in remote rural areas. Under this approach, which has been adopted by sub-national road authorities, certain unsealed roads can become impassable and the comfortable travel speed falls below 35 km/h. This situation improves slightly for unsealed roads assigned the second level of serviceability, but passability is still affected for at least 5 days each year. Based on the 2017 road condition data from Section 7.1.2, 33.4% and 44.1% of proclaimed unsealed roads in South Africa fit the lowest and second lowest levels of serviceability, respectively. This indicates that all-weather passability is potentially impaired on a high proportion of the gravel road network, which has implications for time-sensitive basic services, such as healthcare, and potentially undermines the Department's constitutional obligation to ensure that all citizens enjoy at least the minimum level of access to basic services.

Table 7.11: Required standards as stipulated by the Guidelines for Levels of Serviceability

Level of serviceability	Max roughness (IRI)	Dustiness	Impassability	Comfortable travel speed
5 (lowest)	15	5 (highest)	Frequently	< 35 km/h
4 (low)	11	3 (moderate)	< 5 days per year	45 km/h
3 (moderate)	9	3 (moderate)	Never	60 km/h
2 (high)	8	3 (moderate)	Never	80 km/h
1 (highest)	6	1 (lowest)	Never	> 100 km/h

Source: Department of Transport, 2013.

7.6 CONCLUSION

Because the authorities must accommodate at least some portion of the gravel road network within their available budgets, it is important to understand whether gravel, as the current default option for low-volume roads, is a cost-effective surface solution. In this regard, this study supports four key policy recommendations. Firstly, if a traditional pavement design is required to support a lightly sealed but not a gravel road surface, then it is cost-effective to maintain gravel roads irrespective of their initial condition. However, because the TRH 20 Simplified Design Catalogue specifies the same pavement structure for low-volume gravel and lightly sealed roads, this recommendation does not apply to new roads (Department of Transport, 2013). Moreover, this recommendation applies to a very low proportion of existing unsealed roads. Based on the longstanding principle in TRH 20 that good preparation of the subgrade is extremely important as this should form the subgrade for future improved roads, the specified subgrades have been relatively strong (Department of Transport, 1990; 2013). Given the strength of the historical and current subgrade designs, traffic induced compaction of subgrades over the life of unsealed roads, and the fact that many regions in South Africa possess strong in situ materials, the in situ materials on most of the 454 609 km of existing unsealed roads should provide a strong enough pavement structure to support lightly sealed roads. The following three recommendations are thus the dominant policy conclusions.

Firstly, wherever the in situ subgrade has sufficient bearing strength to support expected traffic volumes without structural upgrading it is cost-effective to seal gravel roads in poor and very poor condition. This finding applies to the 352 301 km of gravel road, or 77.5% of the proclaimed gravel road network, in poor and very poor condition in 2017. Moreover, it is cost-effective to seal any of the 131 919 km of unproclaimed gravel roads in areas with good in situ subgrade if proclaimed.

Secondly, wherever the in situ subgrade has sufficient bearing strength to support expected traffic volumes without structural upgrading it is cost-effective to seal many gravel roads in fair or better condition. This finding applies to the 70 990 km of gravel road in fair condition and 31 319 km of gravel road in good and very good condition in 2017. Given that authorities have tended to maintain higher volume gravel roads in better condition, it is likely that many of these roads should fall within the stress test combinations that render seals more cost-effective than gravel.

Thirdly, new roads should be sealed except under the baseline conditions ideal for gravel road provision. The R186.6 million that provincial authorities spent to construct gravel rather than sealed roads between 2013/14 and 2015/16 could lead to as much as a R6.0 million premium per km over a 30-year period (National Treasury, 2018). A policy to seal new roads presents the provincial and municipal road authorities, who currently face severe funding constraints, with an opportunity to realise significant future budget savings.

There is near-unanimity amongst economists that South Africa's most urgent policy priority is improving the quality and extending the distribution of lower-skilled human capital that has a non-negative shadow value. Such assessment should be done in terms of welfare, not monetary value. However, there is no meaningful room for doubting that, in South Africa, if a policy A dominates or ties with a policy B in terms of expected monetary value, but A contributes more to the human capital stock among citizens with relatively low levels of formal education, than A dominates B with respect to optimizing public utility. This analysis indicates that choosing sealed surfaces over gravel surfaces is an "A-type" policy where the overwhelming majority of real road surfacing decisions are concerned. Because a policy to seal gravel roads is the dominant strategy, the road departments should begin sealing gravel roads worth maintaining at a rate possible within budget limits.

Despite the apparent economic rationale of a policy to seal gravel roads worth maintaining at all, road authorities must cope with the logistical challenge of accommodating the upfront capital costs to seal gravel roads within the budget constraints identified in Chapter 4. To increase the rate at which road authorities are able to roll out their sealing schedules, which should occur for each road in lieu of its next rehabilitation event with the upgrade schedule set using the CEA-based road classification system in Chapter 6 and the road maintenance prioritisation model developed in Chapter 9, two key policy advances championed by this thesis coincided with its late stages of preparation. First, the allocation conditions attached to the Provincial Roads Maintenance Grant have changed to allow upgrades to gravel roads. Second, the Presidential Infrastructure Coordinating Commission has implemented a pilot project to allocate additional public resources – initially R400.0 million – to seal gravel roads.

8 OPTIMISATION OF THE BASIC ACCESS ROAD NETWORK

Another mechanism to minimise the fiscal burden imposed on provincial and municipal road authorities by low-volume roads, thereby avoiding a Hobson's choice between maintenance of roads that provide basic access or roads that maximise growth, is to optimise this network. Both Surplus Roads and single-function Basic Access Roads make a negative contribution to economic growth, however, authorities can only unproclaim roads in the former class as roads in the latter class serve a constitutionally protected basic access function. In order to increase the volume of Surplus Roads that authorities can unproclaim, this chapter identifies potential single-function Basic Access Roads and estimates when it becomes cost-effective to convert these roads into Surplus Roads by removing their basic access function through relocating school and healthcare facilities closer to the relevant communities.

Section 8.1 introduces the two-step floating catchment area (2SFCA) methodology used to identify potential single-function Basic Access Roads. The 2SFCA model is augmented for distance decay and captures the weighted assessment of drive-time to schools, healthcare facilities, and jobs and the ratio of people in a catchment area to teachers and healthcare workers. Sections 8.2 and 8.3 respectively cover the data applied to the 2SFCA model and the empirical strategy.

Section 8.4 identifies the connective road network and drive-time between communities and primary and secondary schools, healthcare facilities, and jobs. Suitability analysis is applied to combine the spatial accessibility to schools, healthcare facilities, and jobs in a Multivariate Road Index. The lowest priority class in this Index approximates the potential single-function Basic Access Road Network and captures 45 757 km of access roads that are both far from schools and healthcare facilities and in areas with very few jobs.

Section 8.5 uses lifecycle cost analysis (LCCA) to compare the maintenance cost of single-function Basic Access Roads with the alternative to relocate existing school and healthcare facilities or to establish new schools and healthcare facilities closer to isolated communities. These two options are tradeoffs as relocating service centres closer to isolated communities removes the access function served by these roads, rendering them Surplus Roads that can be unproclaimed without concern that either economic growth or citizens' basic access rights might be compromised. The potential savings in road maintenance costs, which are shown to amount to between R149.3 billion and R200.6 billion over a 30-year period depending on road types and conditions, can be redirected to roads that maximise growth. Section 8.6 concludes by stressing the significant potential net budget savings identified by this network level optimisation and the need for authorities to follow-up with the necessary project level analyses and decisive action in terms of unproclaiming Surplus Roads.

8.1 2SFCA METHODOLOGY

Previous accessibility studies focused on distance to service centres, with the intention to extend the accessibility measures to include quality and affordability of services (Department of Public Service and Administration, 2011). This paper applies a 2SFCA method, which is a special case of gravity model proposed by Radke and Mu (2000) and modified by Luo and Wang (2003a; 2003b), to measure spatial accessibility to primary and secondary schools and healthcare facilities across South Africa. Noteworthy applications of the 2SFCA method include Owen and Levinson (2014) and Dai and Wang (2011) who measure access to jobs and food stores, respectively.

The first step in the 2SFCA methodology is shown in Equation 8.1. All population locations (k) that are within a threshold travel time (d_o) from location j (the nearest school or healthcare facility) are identified, and the teachers/physicians-to-population ratio (R_j) calculated for the catchment area. P_k is the population at location k whose centroid falls within catchment j ($d_{kj} \leq d_o$), S_j the number of teachers/physicians at location j, and d_{kj} the travel time between k and j.

$$R_j = \frac{S_j}{\sum_{k \in (d_{kj} \leq d_o)} P_k} \qquad 8.1$$

The second step is shown in Equation 8.2, which searches for all locations (j) that are within the threshold travel time (d_o) from location i, and sums the teachers/physicians-to-population ratios from step 1 (R_j) at these locations. A_i^F represents the accessibility of the population at location i to teachers/physicians, R_j is the teacher/physician-to-population ratio at location j whose centroid falls within the catchment centred at population location i, and d_{ij} the travel time between i and j. A larger value of A_i^F indicates better access to teachers or physicians at that population location.

$$A_i^F = \sum_{j \in \{d_{ij} \le d_o\}} R_j = \sum_{j \in \{d_{ij} \le d_o\}} \frac{S_j}{\sum_{k \in \{d_{ij} \le d_o\}} P_k} \quad 8.2$$

Luo and Qi (2009) apply weights in steps 1 and 2 to different travel time zones to address the problem of uniform access within the catchment area. This element of distance decay is accounted for by introducing multiple travel time zones within catchment areas, which are obtained using the ArcGIS Network Analyst and assigned weights according to the Gaussian function. This adapted method, referred to as E2SFCA, is presented in Equation 8.3. The catchment areas for schools and healthcare facilities (location j) are split into n travel time zones, with the weighted teachers/physicians-to-population ratio (R_j) in a catchment area based on the population locations (k) in each threshold travel time zone (D_r).

$$R_j = \frac{S_j}{\sum_{k \in \{d_{kj} \in D_r\}} P_k W_r} \quad 8.3$$

where P_k is the population of grid cell k falling within the catchment j ($d_{kj} \in D_r$), S_j the number of teachers or physicians at location j, d_{kj} the travel time between k and j, and D_r the rth travel time zone within the catchment. W_r is the distance weight for the rth travel time zone calculated from the Gaussian function, capturing the distance decay of access to the teacher or physician j.

The final step in the 2SFCA methodology is presented in Equation 8.4. All of the school and healthcare facilities within the respective travel time zones from location i are identified and the teachers/physicians-to-population ratios (R_j) are then summed. A_i^F is the accessibility of population at location i to teachers or physicians, R_j the teachers/physicians-to-population ratio at teacher or physician location j that falls within the catchment centred at population i, and d_{ij} the travel time between i and j. The same distance weights derived from the Gaussian function used above are applied to different travel time zones to account for distance decay.

$$A_i^F = \sum_{j \in \{d_{ij} \in d_r\}} R_j W_r \qquad 8.4$$

Job accessibility is introduced in the 2SFCA methodology in the same way as schools and healthcare facilities. This is done last with the intention to introduce a proxy for economic activity and alternative road user demand to basic service access. In the absence of network wide traffic data and the application of a structural growth model, work travel is among the only available indicators for structural road demand and economic activity. However, jobs data provides a skewed economic perspective for two reasons: it ignores road freight, which in 2014 facilitated the movement of 231 billion tonne-km, or 85.0%, of land freight flows in South Africa (Havenga et al., 2016); and a disproportionately high number of jobs in rural South Africa are in the bloated public sector. Job accessibility is thus applied to provisionally identify the set of potential single-function Basic Access Roads that authorities can target for rationalisation.

In terms of this rationalisation exercise, the 2SFCA method identifies roads with the following characteristics: low traffic volume; access route to a school or hospital; and located far from schools and healthcare facilities. While relocating service centres to areas with higher traffic volumes may yield marginal improvements in access to basic services, it is unlikely that the cost to realise this outcome can be offset by a concurrent reduction in the road network as single-function Basic Access Roads are generally not present in areas with high volumes of multi-purpose road users. On the other hand, strategically relocating service centres closer to isolated areas with low traffic volumes may render redundant some roads being used almost exclusively to access basic service centres.

Suitability analysis, which weights a standard set of variables according to their importance, is applied to combine the spatial accessibility to schools, healthcare facilities, and jobs in a Multivariate Road Index. The assigned weightings are discrete and linear, with the highest weighting assigned to roads with the best levels of access. This chapter is focused on roads with the lowest weights. Because low weighted roads are typically in areas characterised by a distance constraint to basic service centres and low traffic volumes, authorities can target them for rationalisation through basic service centre relocation.

8.2 DATA

The CSIR compiled a national, provincial, and municipal road network database. The data includes the GPS coordinates of 640 181 km of roads, and importantly the assigned speed limit for each road. The speed limits are set at 40 km/h for streets and tertiary roads, 60 km/h for avenues and secondary roads, 80 km/h for main roads and arterial roads, and 100 km/h to 120 km/h for highways. Unfortunately, no data are available for traffic flow, U-turns, traffic lights, traffic direction, traffic orientation signs, or barriers.

The CSIR (2017) developed a Geospatial Analysis Platform (GAP) that divides South Africa into 25 000 mesozones, each approximately 50 km^2, based on jurisdictional, administrative, physiographic, and historic boundaries and demarcations. The GAP's demographic data are from the 2007 Census, which recorded 48.5 million citizens. Although the 2007 Census data underestimates the population by 6.3% compared to the 2011 Census, the GAP's layout of mesozones and use of dasymetric mapping principles to inform the population distribution provides better detail than the 2011 Census enumeration area data.

The geo-referenced data for the 22 263 ordinary schools and 3 077 healthcare facilities are from the National Department of Basic Education's (2015) School Masterlist Database and the National Department of Health's (2012) 2011-2012 South African Hospital Survey. The information includes the number of doctors, nurses, educators, and students at each facility.

The GAP's employment data were generated from Quantec's 2009 Municipal Survey and the municipal Gross Value Added. Although the 9.55 million total jobs are an underestimate of current employment, it is the best geospatial data of its kind. Because formal employment is recorded per sector per mesozone, jobs are assumed to be uniformly distributed within each mesozone.

8.3 EMPIRICAL STRATEGY

Service areas, which incorporate all regions within a given drive-time from a specific point, are used to determine the place accessibility of schools and healthcare facilities. The drive-time cut-offs are based only on the speed limits as information for traffic flow, U-turns, traffic direction, barriers, traffic lights, and traffic orientation signs are not available. Another access constraint factor is the willingness to pay (WTP) to reach education and healthcare facilities, but unfortunately no estimates for the WTP to access public services exist for South Africa. The result is that some service areas might be overestimated.

The service areas for schools and healthcare facilities were computed for 1-, 3-, 5-, 10-, and 15-minute and 5-, 10-, 15-, 30-, and 45-minute drive-time ranges, respectively. The distance covered in these drive-times at the different speed limits is presented in Table 8.1. The cut-off times are more restrictive for schools given the everyday nature of the service and the official access norms and standards (Government Gazette, 2010). Six geometric classes were created for jobs, with a higher weight assigned to mesozones with more employment. The highest and lowest weights were respectively assigned to mesozones with more than 11 877 jobs or less than 2 jobs. These drive-time ranges generate service area polygons that are joined with the population mesozones to calculate the number of people within each service area cut-off.

Table 8.1: Average travel distance by speed limit

Drive-time	40 km/h	60 km/h	80 km/h	100 km/h
1-minute	0.7 km	1.0 km	1.3 km	1.7 km
3-minutes	2.0 km	3.0 km	4.0 km	5.0 km
5-minutes	3.3 km	5.0 km	6.7 km	8.3 km
10-minutes	6.7 km	10.0 km	13.3 km	16.7 km
15-minutes	10.0 km	15.0 km	20.0 km	25.0 km
30-minutes	20.0 km	30.0 km	40.0 km	50.0 km
45-minutes	30.0 km	45.0 km	60.0 km	75.0 km

Source: Own calculations.

Roads are then assigned a discrete and linear weighting, ranging from 0-5. As shown in Table 8.2, roads within service areas with the highest level of accessibility are weighted 5 and those within service areas with the lowest accessibility are weighted 0. The Multivariate Road Index is a summation of the weights for the accessibility of service areas to schools, healthcare facilities, and jobs. The resultant prioritisation model has 16 priority levels from zero to fifteen.

Table 8.2: Prioritisation weights based on drive-times

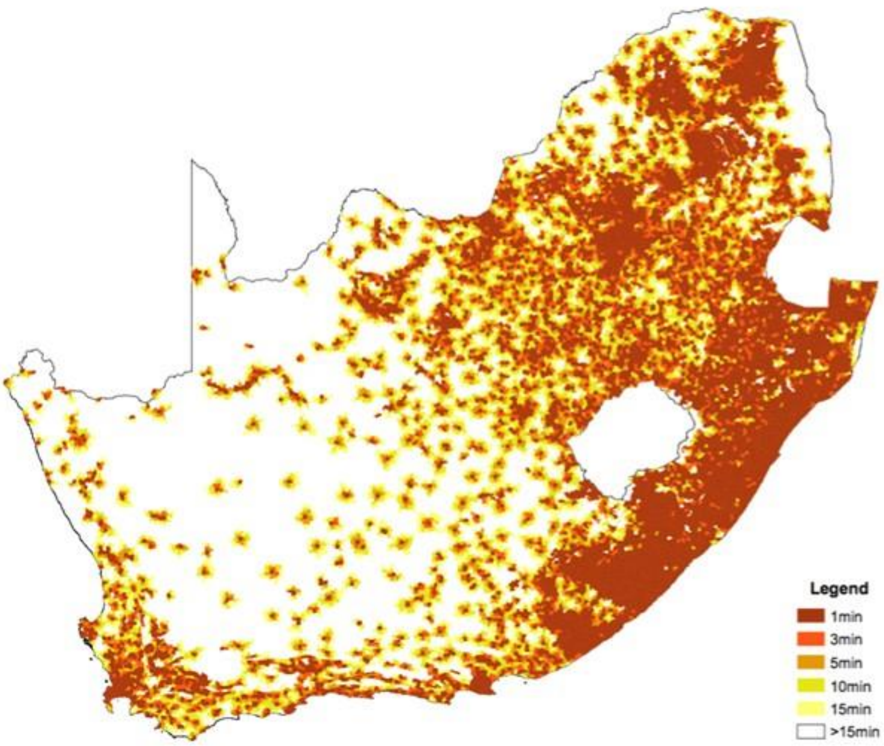
Weight	Schools	Hospitals	Jobs
5	1-minute	5-minutes	> 11 877
4	3-minutes	10-minutes	1 189 – 11 876
3	5-minutes	15-minutes	120 – 1 188
2	10-minutes	30-minutes	13 – 119
1	15-minutes	45-minutes	2 - 12
0	> 15-minutes	> 45-minutes	0 – 1

Source: Own calculations.

8.4 2SFCA RESULTS

Figure 8.1 illustrates the roads within the service areas for the relevant drive-time cut-offs to schools. The analysis indicates that 300 000 citizens, or 0.6% of the population, are further than a 15-minute drive-time from the nearest school. Although a small proportion of the total population are in service areas more than a 15-minute drive-time from the nearest school, these isolated service areas contain 22.5% of the total road network. This diminishing ratio of population coverage to network distance means that a portion of 144 000 km of road are used by only 300 000 people to access basic education facilities.

Figure 8.1: The road network within the school service areas

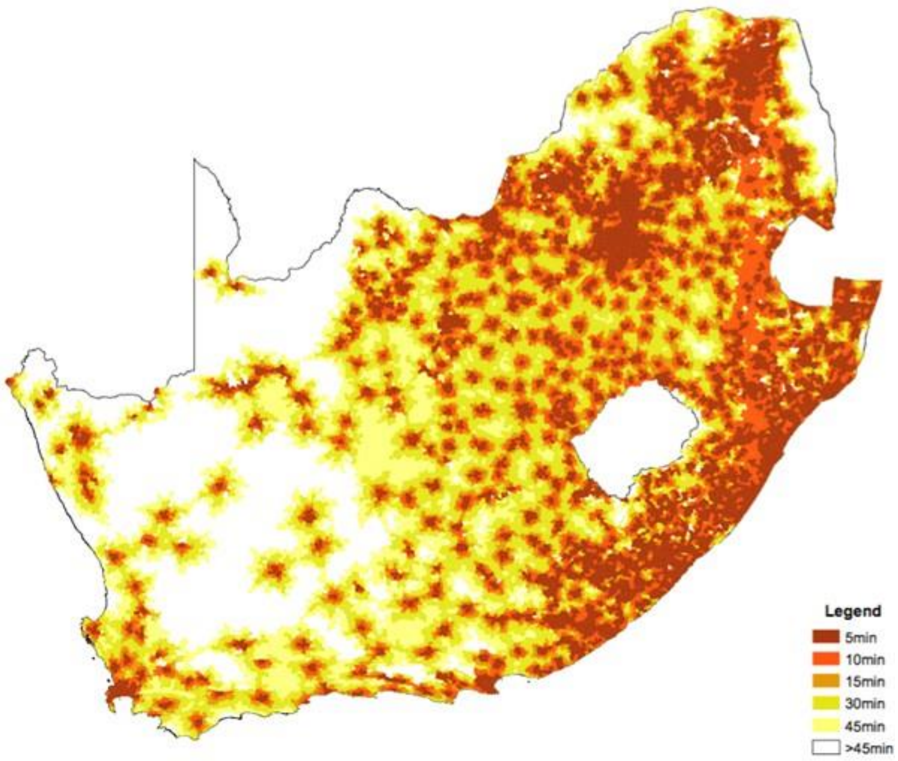


	Drive-time to the nearest school				
	1-minute	**3-minutes**	**5-minutes**	**10-minutes**	**15-minutes**
People covered	46.7 million	47.4 million	47.7 million	48.1 million	48.2 million
% of population	*96.3 %*	*97.7 %*	*98.4 %*	*99.2 %*	*99.4 %*
Length of road	143 042 km	266 594 km	329 259 km	432 259 km	496 000 km
% of road network	*22.3 %*	*41.6 %*	*51.4 %*	*67.5 %*	*77.5 %*

Source: Own calculations.

Figure 8.2 illustrates the roads within the service areas for the relevant drive-time cut-offs to healthcare facilities. Similar to the finding for schools, the proportion of roads in the isolated service areas is relatively high compared to number of people. In the most isolated service area, which is more than a 45-minute drive-time to the nearest healthcare facility, there was 0.2% of the population but 7.1% of the road network. Moreover, service areas between a 30- and 45-minute drive-time to the nearest healthcare facility house 0.6% of the population but 10.0% of the road network. The findings indicate that a portion of 270 181 km of road are used by only 1.7 million people to access basic healthcare facilities.

Figure 8.2: The road network within the healthcare facility service areas

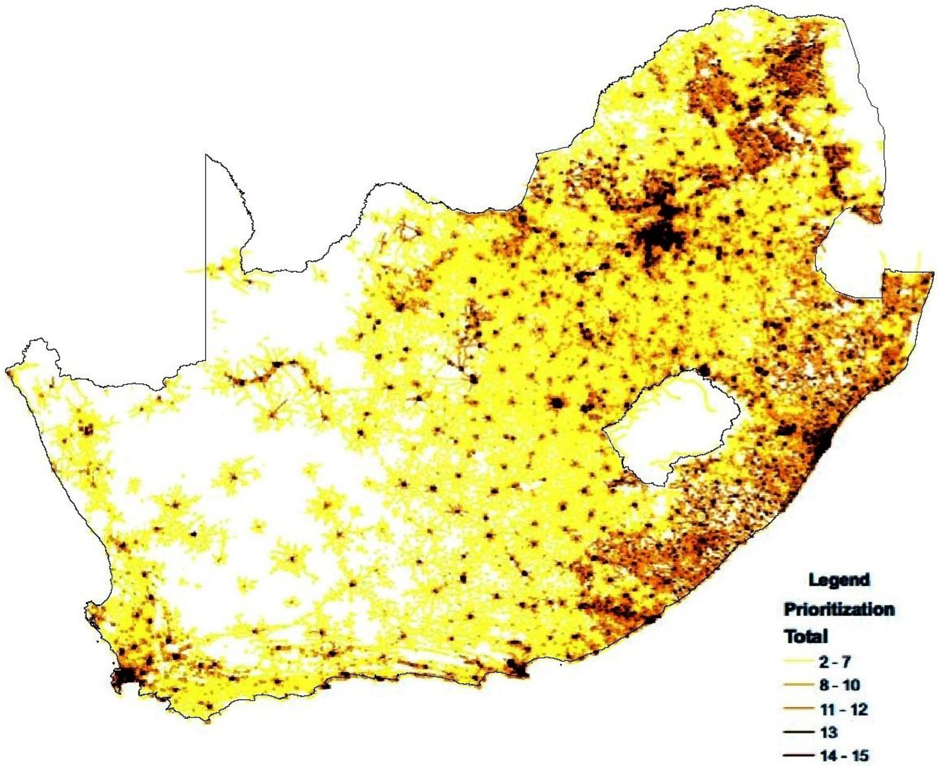


	Drive-time to the nearest healthcare facility				
	5-minutes	**10-minutes**	**15-minutes**	**30-minutes**	**45-minutes**
People covered	42.0 million	45.8 million	46.8 million	48.1 million	48.4 million
% of population	*86.6 %*	*94.4 %*	*96.5 %*	*99.2 %*	*99.8 %*
Length of road	182 000 km	301 000 km	370 000 km	531 000 km	595 000 km
% of road network	*28.4 %*	*47.0 %*	*57.7 %*	*82.9 %*	*92.9 %*

Source: Own calculations.

The composite road map shown in Figure 8.3 draws on the school, healthcare facility, and job accessibility information to classify the South African road network according to access levels. There are 45 757 km of roads in the lowest priority class, which includes service areas with less than 2 formal jobs and further than a 15- and 45-minute drive-time to the nearest school and healthcare facility. Although the exact number is not known without the application of a structural growth model, the present value of the maintenance cost for some of these 45 757 km of road is likely to exceed their economic contribution. This composite road map thus provides authorities with a preliminary indication of the location and extent of single-function Basic Access Roads.

Figure 8.3: Basic Access Road Network by maintenance priority



Source: Own calculations.

8.5 OPTIMISATION ANALYSIS

Lifecycle cost analysis (LCCA) is applied to compare the whole-life cost of low-volume roads with the alternative cost of relocating or constructing new schools and healthcare facilities closer to isolated communities. The analysis is focused on road authority costs and uses a standard discount rate of 10.0% to convert all costs that occur throughout the lifecycle of each option to their Net Present Value (NPV) (Zhuang *et al*., 2007). The analysis period is 30-years, which is longer than the design life of the road options and equal to the life for school and healthcare infrastructure (CIDB, 2009).

8.5.1 Costs to construct, operate, and maintain infrastructure

8.5.1.1 *Low-volume roads*

Because single-function Basic Access Roads typically carry low traffic volumes they tend to be surfaced with either gravel or at most a light seal. Although Chapter 7 finds that if a road is worth maintaining at all it is worth sealing, sealing the 454 609 km gravel network can only happen at a pace manageable within budget limits. Single-function Basic Access Road will therefore comprise of, at least over the medium term, a combination of few lightly sealed roads and mostly gravel roads.

The road condition data reported in Chapter 4 identified 19.8% of proclaimed surfaced roads and 77.5% of proclaimed unsealed roads in poor and very poor condition in 2017. The proportion of roads in poor and very poor condition are likely higher for low-volume roads as authorities have typically focused their maintenance efforts on roads carrying higher traffic. Based on the TRH 4 trigger method, roads in good and very good condition initially require routine maintenance and roads in poor and very poor condition initially require rehabilitation (COTO, 1996). Table 8.3 applies the road agency costs listed in Chapter 7 to compare the 30-year lifecycle cost to provide low-volume 6.0 m wide gravel roads and 6.8 m cape sealed roads under the different conditions present in South Africa assuming an average haulage distance of 25.0 km. The gravel road costs reflect an 8-year regravelling cycle.

Table 8.3: 30-year lifecycle cost for different low-volume road types, 2018

Road surface	Initial VCI	Conditions	PV per km (R)
Gravel	Good condition	Flat gradient & moderate climate	2 518 270
		Steep gradient & moderate climate	3 727 767
		High moisture & flat gradient	3 489 004
	Poor and very poor condition	Flat gradient & moderate climate	3 480 404
		Steep gradient & moderate climate	4 996 442
		High moisture & flat gradient	4 604 408
Cape seal	Upgrade from gravel using in situ subgrade / Poor condition	Flat gradient & moderate climate	3 471 881
		Steep gradient & moderate climate	4 175 669
		High moisture & flat gradient	3 958 865
	Good condition	Flat gradient & moderate climate	1 746 205
		Steep gradient & moderate climate	1 947 789
		High moisture & flat gradient	1 881 750

Source: Own calculations.

8.5.1.2 *Primary and secondary schools*

The Government Gazette (2013) published the R*egulations Relating to Minimum Uniform Norms and Standards for Public School Infrastructure*. As the focus is on providing small, isolated communities with enhanced access to basic service facilities the following set of standardised ordinary schools are assessed: micro primary schools with 25 or 65 students; small primary schools with 135 students; and small secondary schools with 200 students. Larger facilities are not covered given the low volume of students in isolated rural areas.

Table 8.4 details the minimum requirements for an enabling school environment prescribed by the Norms and Standards and the relevant unit costs. The unit costs are approximations based on project data and best estimates. Variations in cost may occur across provinces and according to key variables such as the distance from building supplies and availability of bulk services and land. The average cost for both schools and healthcare facilities omit the purchase price of land as rural chiefs often allocate tribal land for basic services. Cost escalations are thus required where this is not the case.

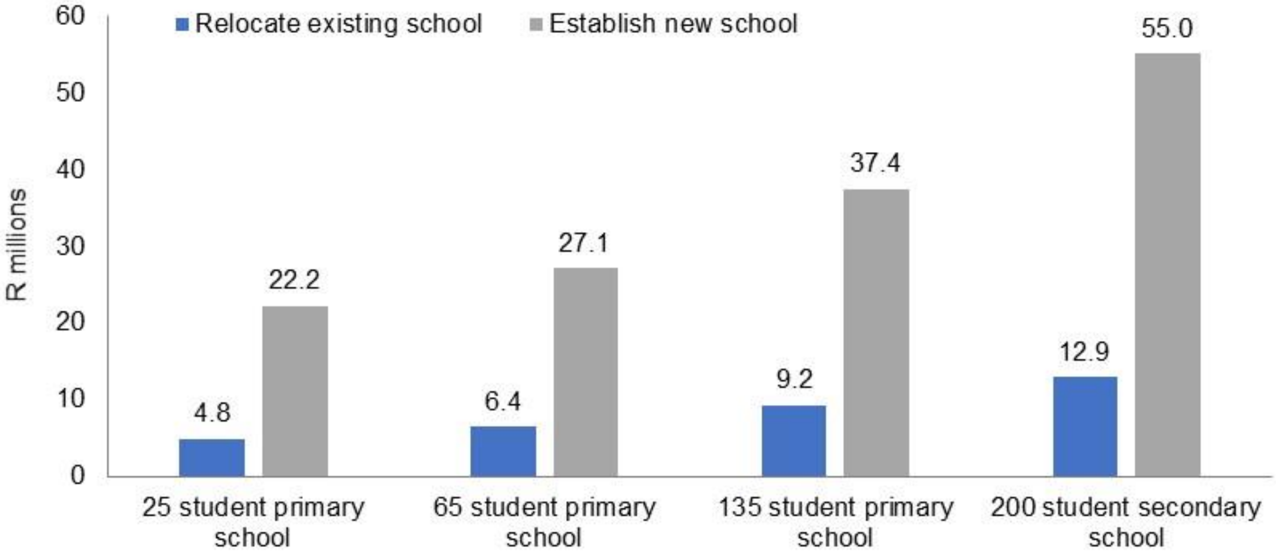
Table 8.4: Minimum requirements for an enabling school environment, 2018

Cost variables	Unit cost (R)	Units required for school size			
		Number of students			
		25	65	135	200
Capital costs					
Grade R class	870 000	1.0	1.0	1.0	0.0
Classrooms	696 000	1.0	2.0	4.0	5.0
Multi-purpose room	870 000	1.0	1.0	1.0	1.0
Multimedia centre	2 207 500	0.5	0.5	1.0	1.0
Science lab	2 187 500	0.0	0.0	0.0	1.0
Principal's office	290 000	1.0	1.0	1.0	1.0
Admin office	290 000	1.0	1.0	1.0	1.0
Strong room	145 000	1.0	1.0	1.0	1.0
Staff room	870 000	0.0	1.0	1.0	1.0
Sick room	217 500	0.0	0.0	0.0	1.0
Kitchenette	174 000	1.0	1.0	1.0	1.0
HOD's office	217 500	0.0	0.0	0.0	1.0
Printing room	217 500	0.0	0.0	0.0	1.0
Full sanitation block	600 000	0.5	0.5	1.0	1.0
Storage rooms	174 000	0.0	0.0	0.0	6.0
Nutrition centre	100 000	1.0	1.0	1.0	1.0
Annual operating costs					
Principal	657 558	1.0	1.0	1.0	1.0
HOD	334 545	0.0	0.0	0.0	1.0
Educators	240 519	2.0	3.0	5.0	6.0
Admin support	194 820	0.0	0.0	0.0	1.0
Management staff	194 820	1.0	1.0	1.0	3.0
Electricity & water	100 000	1.0	1.0	2.0	2.0

Source: Government Gazette, 2013; Department of Planning, Monitoring and Evaluation, 2017; National Library of South Africa, 2017; International Budget Partnership, 2017; Department of Public Works, 2013; KwaZulu-Natal Department of Education, 2011.

The CIDB (2009) set annual maintenance costs at 5.0% of the replacement value of school infrastructure and the discount rate is set at 10.0% as per Chapter 7. Based on these variables and the information in Table 8.4, Figure 8.4 presents the discounted present value (PV) of the lifecycle cost to relocate existing schools and to construct, maintain, and staff new schools. Additional operating costs are not applicable to the relocation scenario as the facilities currently exist and post-relocation are expected to operate as usual. The estimated PVs correlate with the project costs recorded by the Department of Public Works (2013).

Figure 8.4: The PV of the lifecycle cost to relocate existing schools and to construct, maintain, and staff new schools, 2018



Source: Own calculations.

8.5.1.3 *Healthcare facilities*

The main determinants for the cost of healthcare facilities is the population served and the services rendered. The relevant healthcare facilities for rural communities are clinics, with mobile or satellite clinics provided for very small populations. Clinics operate on weekdays, with maternity services provided by a midwife on call and birthing complications identified during anti natal care visits. As such no housing units are provided for waiting mothers and complex cases are referred to the nearest district hospital or community health centre (CHC) where a 24-hour service is available. Clinics serving up to 8 000 and 30 000 people therefore consist of 2 and 4 consulting rooms, respectively. There are 2 070 of these clinics across South Africa, with 67.0% of all clinics in this size range.

Clinics with 2 consultation rooms ideally occupy a 429m^2 complex and include 1 vitals room, 1 emergency room, and a gatehouse with visitor toilets. Clinics with 4 consultation rooms ideally occupy a 524m^2 complex and in addition to the above facilities have 1 counselling room, 1 multi-purpose community room, and 1 chronic medication dispensing depot. The province specific costs shown in Table 8.5 for these clinic categories were derived from the

National Department of Health's (2018) cost estimator. Because the facilities are planned for rural areas the costs account for 200 km transport from the nearest builder's supply and installation of bulk services. The annual operating costs are comprised of infrastructure and health technology maintenance, medical supplies, and human resources. The Department of Health claim that the estimates are within 15.0% of actual costs.

Table 8.5: Estimated clinic costs, 2018

	Costs for 429m^2 facility (R)		**Costs for 524m^2 facility (R)**	
Province	Capital	Annual operations	Capital	Annual operations
Eastern Cape	18 474 535	4 727 982	22 403 431	5 043 319
Free State	18 630 688	4 730 166	22 594 793	5 045 989
Gauteng	17 481 628	4 711 183	21 193 539	5 023 241
KZN	18 006 077	4 721 432	21 829 345	5 035 307
Limpopo	18 705 342	4 735 097	22 677 087	5 051 395
Mpumalanga	18 688 015	4 732 631	22 635 940	5 048 692
North West	17 574 946	4 717 347	21 296 407	5 029 998
Northern Cape	18 861 495	4 737 280	22 868 449	5 054 065
Western Cape	18 574 697	4 726 467	22 533 072	5 041 935
National average	**18 333 047**	**4 726 621**	**22 225 785**	**5 041 549**

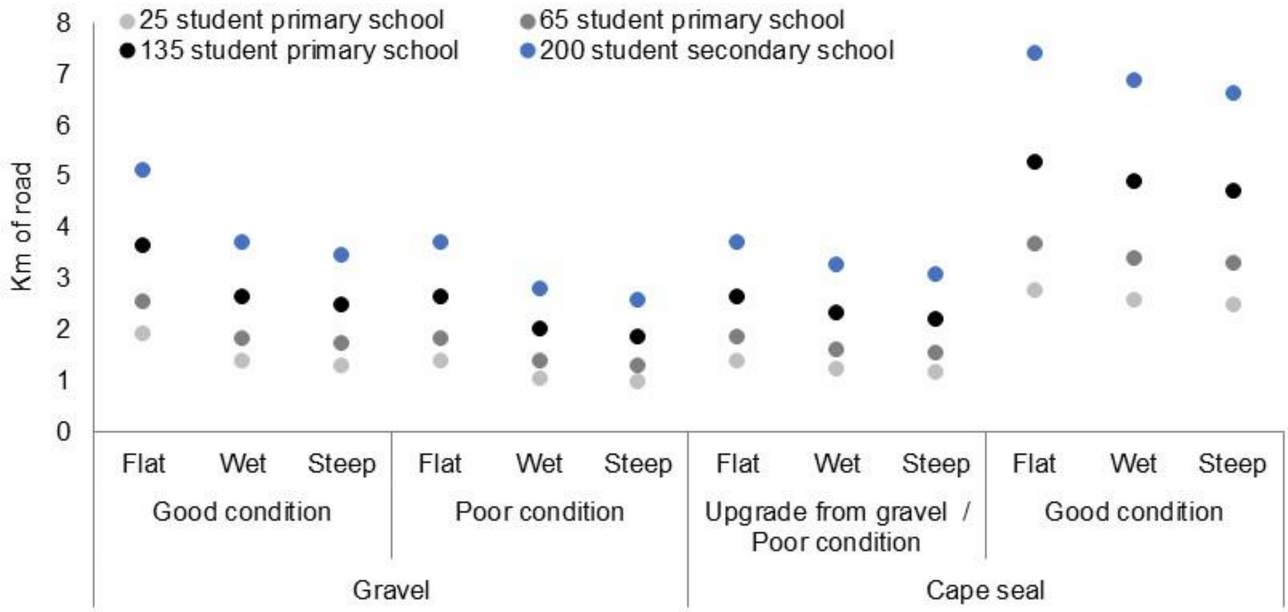
Source: National Department of Health, 2018.

Applying the same 10.0% discount rate as for schools, the PV of the average lifecycle cost to relocate existing clinics is R18.3 million for a 429m^2 facility and R22.2 million for a 524m^2 facility. Alternatively, the PV of the average lifecycle cost to construct, maintain, and staff a new 429m^2 and 524m^2 clinic is R67.3 million and R74.5 million, respectively.

8.5.2 The trade-offs between road maintenance and school locations

Figure 8.5 compares the lifecycle cost to maintain roads with the cost to relocate schools. Because school relocation incurs an upfront capital cost but no additional operating costs, the basic access function must be removed from fewer single-function Basic Access Roads before it becomes cost-effective for authorities to relocate existing schools closer to isolated communities. It is cost-effective to relocate a 25 student primary school, 65 student primary school, 135 student primary school, and 200 student secondary school if the road network is respectively rationalised by at least 1.4 km, 1.8 km, 2.6 km, and 3.7 km of poor and very poor condition gravel roads in a moderate climate with flat terrain. The same approximate thresholds apply were authorities to decide to seal these gravel roads. In the unlikely event that the gravel roads are in good condition, the most the road network must be rationalised by is 5.1 km to justify relocating a 200 student secondary school. The estimated breakeven distances, at which point the road maintenance savings from a reduced road network offset the cost to relocate schools, are relatively short compared to the accessibility analysis in Chapter 3 which found that the most isolated students must potentially travel 101.1 km and 122.1 km to access their nearest primary and secondary school, respectively. Moreover, the 2SFCA identified 122 081 km of proclaimed roads more than a 15-minite drive-time from the nearest school. The point at which reduced road maintenance costs breakeven with the cost to relocate or establish new service centres are lowered for both schools and clinics if roads have steep gradients or are in wet regions.

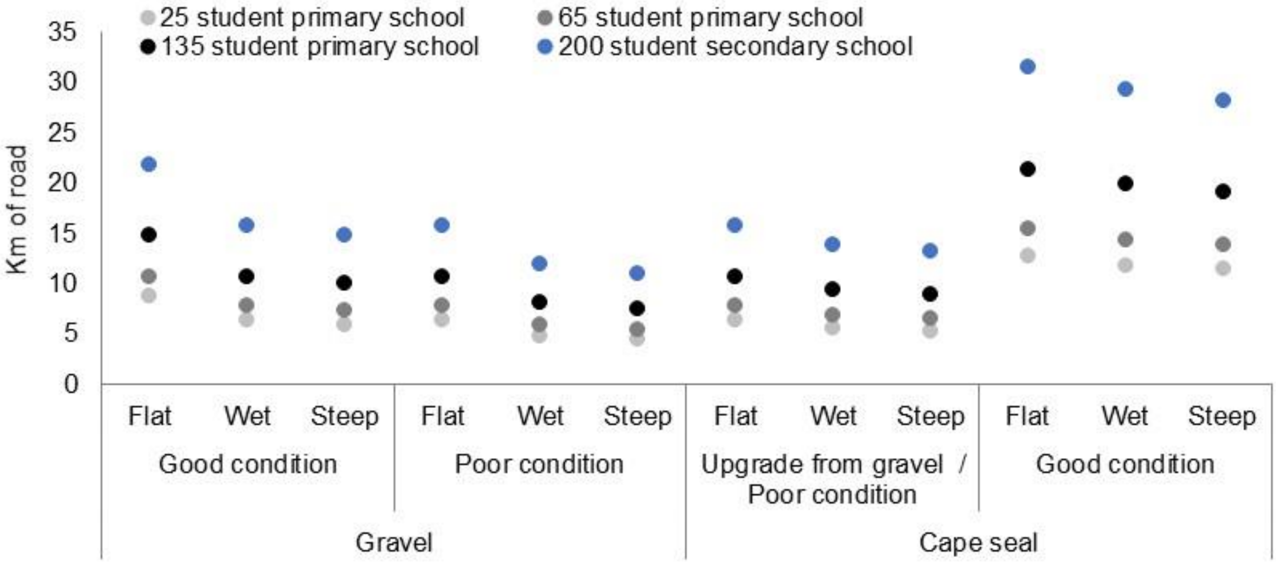
Figure 8.5: The length of road at which lifecycle road maintenance costs breakeven with the cost to relocate existing schools



Source: Own calculations.

Figure 8.6 compares the lifecycle cost to maintain roads with the cost to construct, maintain, and staff new schools. The additional operating costs associated with new school facilities mean that the access function must be removed from a higher distance of single-function Basic Access Roads before it is cost-effective for authorities to establish new schools closer to isolated communities. It is cost-effective to establish a new 25 student primary school, 65 student primary school, 135 student primary school, and 200 student secondary school if authorities can respectively rationalise at least 6.4 km, 7.8 km, 10.7 km, and 15.8 km of poor and very poor condition gravel roads in a moderate climate with flat terrain. Approximately the same length of road must be rationalised to justify establishing a new 25 student primary school, 65 student primary school, 135 student primary school, and 200 student secondary school were these gravel roads upgraded to a light bituminous seal. Although the breakeven distances are longer than for the relocation of schools, they are still relatively short compared the estimated spatial separation between isolated students and primary and secondary schools mentioned above.

Figure 8.6: The length of road at which lifecycle road maintenance costs breakeven with the cost to establish new schools

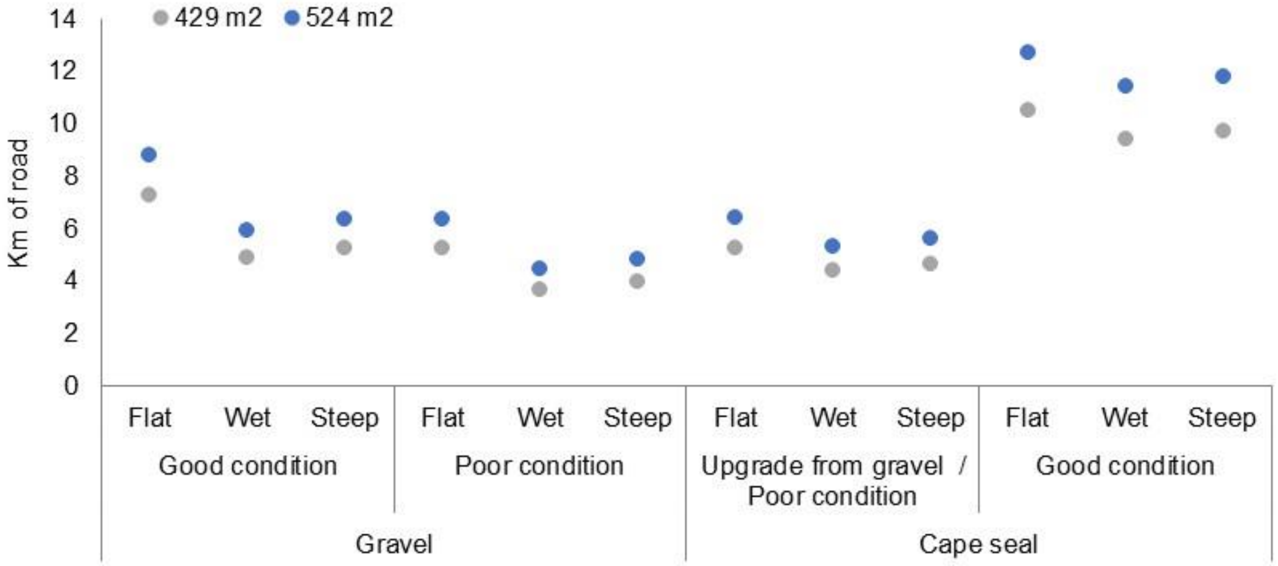


Source: Own calculations.

8.5.3 The trade-offs between road maintenance and clinic locations

Figure 8.7 compares lifecycle road maintenance costs with the cost to relocate the two clinic types. At least 5.3 km and 6.4 km of poor and very poor condition gravel roads, and similarly gravel roads upgraded to a light bituminous seal, in a moderate climate with flat terrain must be removed from the road network before it is cost-effective to respectively relocate a 429m^2 and 524m^2 clinic closer to isolated communities. If the gravel roads are in a good condition then relocating a 429m^2 and 524m^2 clinic is cost-effective once 7.3 km and 8.8 km of single-function Basic Access Roads are respectively removed from the network. These estimated breakeven distances are relatively short compared to the accessibility analysis in Chapter 3 which found that the most isolated communities are potentially as far as 117.5 km from the nearest healthcare facilities. In addition, the 2SFCA identified 87 081 km of proclaimed roads more than a 30-minite drive-time from the nearest healthcare facility.

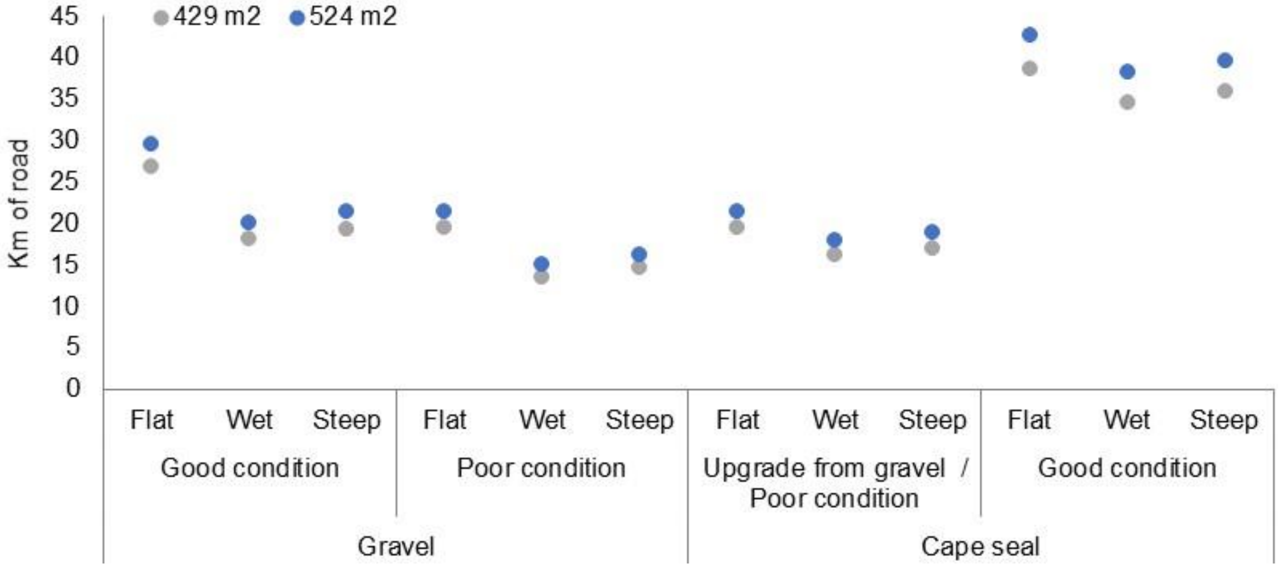
Figure 8.7: The length of road at which lifecycle road maintenance costs breakeven with the cost to relocate existing clinics



Source: Own calculations.

Figure 8.8 compares the lifecycle cost to maintain roads with the cost to construct, maintain, and staff new clinics. The significant capital and operating costs associated with clinics mean that a relatively high distance of single-function Basic Access Roads must be removed from the network under the specified conditions to justify constructing additional clinics. At least 19.4 km and 21.4 km of poor and very poor condition gravel roads as well as gravel roads upgraded to a light bituminous seal in a moderate climate with flat terrain must be removed from the network for it to be cost-effective to respectively relocate a 429m^2 and 524m^2 clinic closer to isolated communities. If the gravel roads are in a good condition then relocating a 429m^2 and 524m^2 clinic is cost-effective once at least 26.7 km and 29.6 km of single-function Basic Access Roads are respectively removed from the network. Although the road network reductions needed to justify establishing new clinics are relatively onerous, it remains a realistic option given the access constraints to healthcare mentioned earlier.

Figure 8.8: The length of road at which lifecycle road maintenance costs breakeven with the cost to establish new clinics

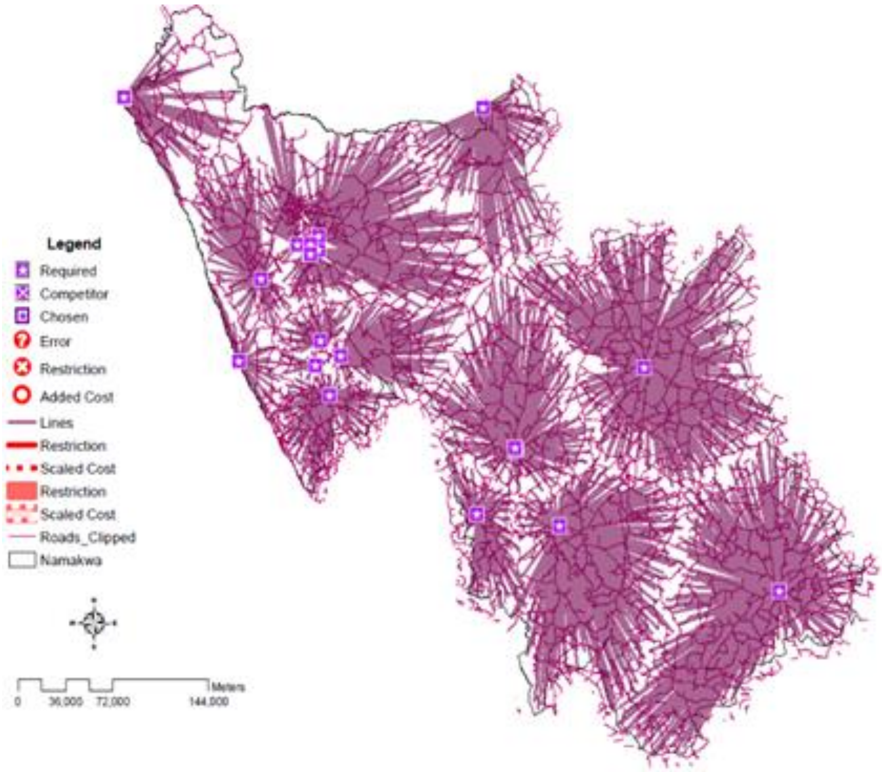


Source: Own calculations.

8.5.4 Optimisation simulations

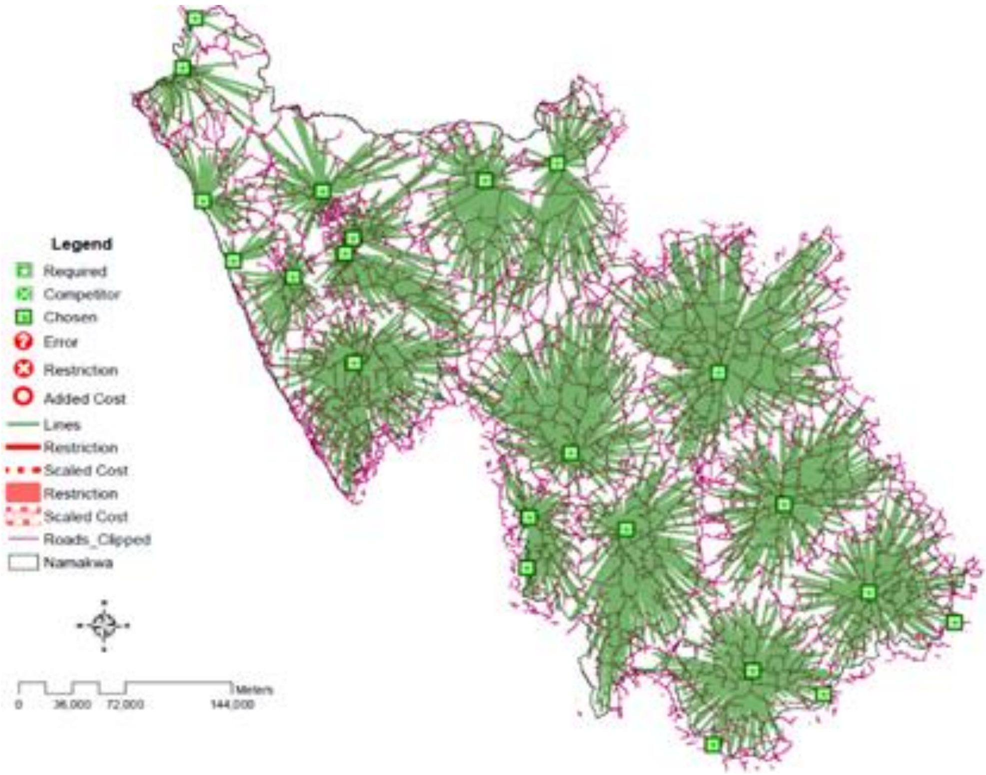
Figures 8.9 and 8.10 compare the current versus optimal location of healthcare facilities in the Namakwa District Municipality in the Northern Cape. This municipality was chosen to simulate the effect of service centre relocation on road access to healthcare facilities due to the wide distribution of healthcare facilities and combination of urban and rural communities. The simulated healthcare facility locations shown in Figure 8.10 intend to maximise access and minimise drive-time. While variations between the current and optimised locations are marginal, the changes significantly improve access conditions when the analysis is re-run. The visible reduction in the distance of the catchment zones equates to a 20.0% reduction in average drive-time to the nearest facility.

Figure 8.9: The accessibility of current healthcare facilities in Namakwa District Municipality



Source: Own calculations.

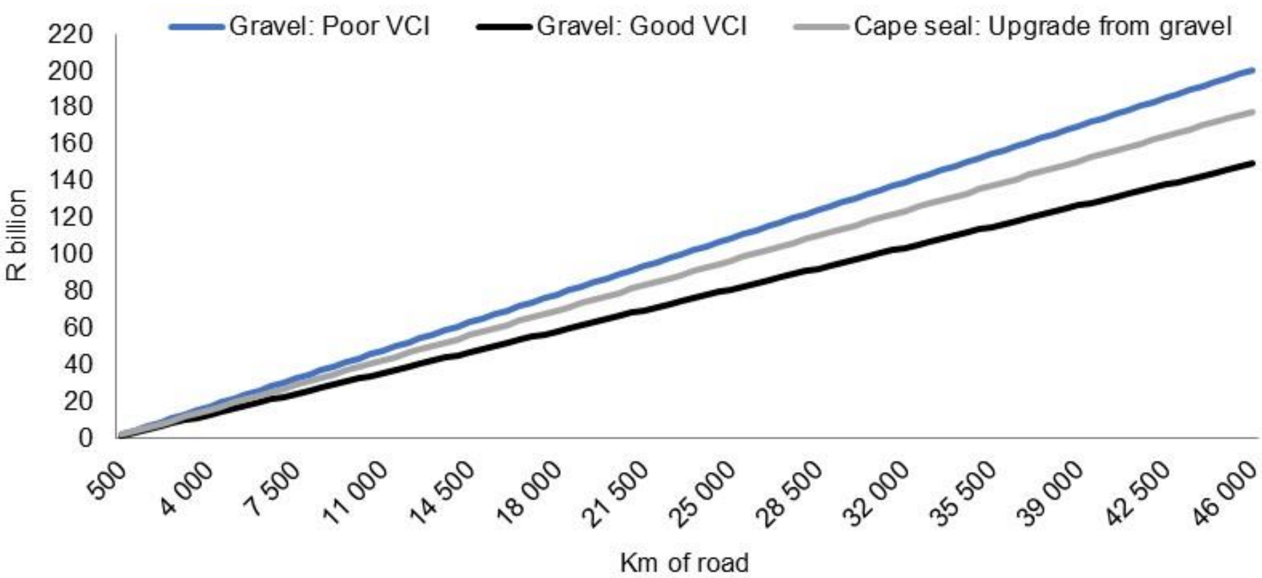
Figure 8.10: The accessibility of simulated healthcare facilities in Namakwa District Municipality



Source: Own calculations.

Bearing in mind the breakeven distances estimated in Sections 8.5.2 and 8.5.3, which will affect the net budget savings, Figure 8.11 presents the potential lifecycle road maintenance cost savings that authorities could realise by rationalising some portion of the 45 757 km of roads in the lowest priority class through service centre relocation. Were authorities able to convert this entire set of roads into Surplus Roads the potential saving amounts to R200.6 billion, R149.3 billion, or R178.0 billion if these roads were poor condition gravel roads, good condition gravel roads, or gravel roads to be sealed, respectively. Every 1.0%, or 457.6 km, reduction in the road network would free up between R1.5 billion and R2.0 billion that could be redirected to the maintenance of other more productive roads.

Figure 8.11: Potential 30-year road maintenance cost savings



Source: Own calculations.

8.6 CONCLUSION

This analysis demonstrates that service centre relocation presents authorities with a means through which to create significant redundancies amongst the single-function Basic Access Road Network. Authorities can then unproclaim these redundant roads along with the other Surplus Roads, thereby freeing up constrained road maintenance funds for use on growth-promoting road infrastructure.

However, political, socio-economic, and cultural processes often dominate attendance and catchment area considerations related to basic services. For example, relocating schools and healthcare facilities might require staff to live in undesirable locations. Moreover, the relocation of schools and healthcare facilities to optimal locations may require a complicated negotiation process as the exercise shifts expenditure responsibilities between departments and levels of government. The results of this analysis should therefore not be regarded as immediate policy proposals, but rather as indicating planning options that merit democratic deliberation and consultative consideration.

It is important that authorities complete this process of road network optimisation prior to setting up toll routes on provincial or municipal roads, which is currently being explored as an option to generate additional funding for road maintenance. Tolling efficiency is to a large degree reliant on user behaviour. If authorities have not removed redundant routes from the road network then road users are presented with more opportunities to divert from toll roads to alternative routes, thereby lowering toll revenue whilst increasing the maintenance and upgrade demands on the alternative route. If toll routes divert traffic to previously redundant roads, then authorities also lose the opportunity to unproclaim these roads.

9 PRIORITISING GROWTH-PROMOTING ROAD INFRASTRUCTURE

The South African economy is heavily reliant on export performance to realise the economic growth targets set by the National Development Plan (NDP). Road authorities can enhance the productivity of firms, thereby helping them to competitively engage in international trade, by adequately maintaining the sets of roads that minimise the transportation costs between suppliers and production and export points. The important contribution of road maintenance to the international competitiveness of South African firms is emphasised by the transport-intensity of the South African economy, with inland logistics costs accounting for 41.8% of the total international trade logistics costs and 4.9% of the value of all traded commodities for South Africa in 2014 (Havenga *et al.,* 2016). These inland logistics costs, which are the single largest contributor to South Africa's international trade logistics costs, comprise 55.4% transportation costs with 61.1% of the total land freight flow in 2014 moved by road.

Given that the budget constraints identified in Chapter 4 mean that provincial and municipal road authorities cannot maintain road links between all origins and destinations, authorities must prioritise the maintenance of those roads on which increased transportation costs from ruptured or deteriorated service would impose the highest potential economic cost. This chapter therefore develops and tests a road maintenance prioritisation model that enhances the efficiency with which export products flow through South Africa's rural road network en route from production to export points. The prioritisation objective is to minimise transport costs imposed on the maximum volume of export freight for a set road maintenance budget, thereby raising the productivity of local export producers. This objective reflects the NDP policy to stimulate economic growth through international trade and the consensus among most economists that South Africa's economic growth largely depends on a successful export-orientated strategy (National Planning Commission, 2012).

Authorities should apply this road maintenance prioritisation model following maintenance of the Basic Access Road network, which as discussed in Chapter 6 will also include some volume of growth-promoting roads through the Multi-functional Strategic Roads and Multi-functional Tactical Roads. The model will then determine how the remaining budget should be allocated among the Single-function Strategic Roads and Single-function Tactical Roads, which both have a single normative objective to support economic growth. As explained in

Chapter 6, Strategic Roads in urban areas must be removed from the analysis and prioritised separately by the relevant municipal road department to address issues around congestion.

The worst-case scenario for the potential application of the prioritisation model is that there is insufficient budget remaining for authorities to reach Single-function Strategic Roads and then Single-function Tactical Roads, which were respectively set in Chapter 6 as the second and third lexicographical priorities. However, the analysis of the potential Basic Access Road Network in Chapter 6 and the network optimisation measures developed in Chapters 7 and 8 suggest that this prioritisation model should apply to varying degrees to all the provincial and municipal road authorities. The model is therefore designed to be scaled to all possible ranges given constantly evolving maintenance needs and budget allocations.

Section 9.1 begins with a methodological innovation, which is to recognise that the problem at hand is to help policymakers optimally allocate fixed road maintenance budgets according to the policy priority to maximise economic growth. The alternative economic task would be to determine an optimal road maintenance budget, but Sugden (2012; 2018) argues against the practical relevance of such an exercise as the resultant policy advice is separated from real political features in South Africa. Because road maintenance budgets are exogenously set through budgeting and political processes, rather than by a benevolent social planner, the economic focus shifts to ensuring that the allocated funding is spent efficiently.

Section 9.2 firstly establishes that road infrastructure investment has had a positive impact on economic growth in South Africa. The components of demand for domestic goods and services in South Africa are then assessed to demonstrate that economic growth is, as per the NDP policy prescriptions, best served by increasing exports. This decision to prioritise maintenance of roads that support the productivity of South Africa's export sector is framed within international trade theory. According to the theory of regional development, the road maintenance prioritisation model prioritises roads that have higher freight traffic over roads with lower freight traffic that service underdeveloped regions with growth potential.

The potential impact road links have on firms' productivity is assessed in Section 9.3 using a cost function rather than a production function approach as the intended outcome is to efficiently distribute the exogenously determined provincial and municipal road maintenance budgets among these networks. Although cost function models are typically inappropriate when applied to systems with redundancy waste, as when optimising urban road networks, the approach is well-suited to this study where the focus is restricted to Strategic and Tactical Roads that only occur in rural and peri-urban areas.

Section 9.4 motivates and describes the project evaluation methodology that informs the road maintenance prioritisation model. This study applies cost-effectiveness analysis (CEA) given that: there is insufficient data to undertake an accurate full benefit-cost analysis (BCA); the road maintenance budget is exogenously fixed; the investment objective is restricted to export-led growth; and the application of the prioritisation model is intended for rural and peri-urban roads. The empirical strategy is also addressed, covering the imposed budget constraint as well as the decisions to set the project costs as the road agency costs and the effectiveness measure as heavy vehicle-km. Important limitations of the prioritisation model are also noted, including the shortfall that this approach cannot guarantee that a road project has a positive Net Present Value (NPV). However, the prioritisation model does ensure that roads are properly evaluated relative to one another and that the prioritised roads support the highest volume of established export freight for a given investment.

The road maintenance prioritisation model is applied to the Mpumalanga provincial road network in Section 9.5 as an example. The model determines a maintenance schedule for 2017/18 using the 2016 road network data and 2017/18 maintenance budget. The heavy vehicle-km supported by the prioritised road network are compared to the actual outcomes and alternative approaches, such as prioritising maintenance of surfaced roads over gravel roads or roads in higher functional classes, to confirm that the method generates a pareto improvement. The prioritised road maintenance schedule is also reviewed in relation to land use patterns, the rail network, and Gross Value Added (GVA) to demonstrate that it supports significant transportation corridors and production zones.

Section 9.6 concludes by summarising the potential benefits associated with the proposed road maintenance prioritisation model. Included in the discussion are the limitations imposed on the application of the prioritisation model in South Africa, which were shown by the case study, and the data requirements to better specify the effectiveness measure. The purpose of the prioritisation model is not to replace the current Road Asset Management Systems (RAMS), but rather to extend their functionality to ensure that constrained road maintenance budgets maximise potential economic growth in South Africa.

9.1 ALIGNING THE PRIORITISATION MODEL WITH POLITICAL FEATURES

The objective of the road maintenance prioritisation model is to optimally allocate available resources among the set of alternative road projects. This objective can be contrasted with the conventional welfarist exercise, which is to determine an optimal allocation for road maintenance as a function of a welfare optimising overall public expenditure schedule. Although it would be interesting as a theoretical exercise to estimate the optimal budget allocation for roads, knowledge of this policy ideal would have minimal practical effect as the assessment and resultant advice are misaligned with the political processes that determine budget allocations in democratic countries such as South Africa.

The motivation to move from a conventional welfarist approach towards a practical approach focused on optimal allocation of exogenously (politically) given road maintenance resources is based on arguments of Sugden (2012; 2018), who questions attempts by economists to address their policy advice to an imagined, benevolent social planner whose objective is to maximise the overall well-being of society. Such planners, as Sugden points out, do not exist. Actual planners have neither the disinterested and universalist utility functions of the imaginary planner, nor the power to implement the kinds of general equilibrium solutions identified by optimal welfare estimations. Economists' advice, Sugden argues, should focus on feasible recommendations addressed to actual agents who are able to act on the recommendations in question within the constraints of political and institutional decision-making processes.

The precedent for this practical approach was established in Chapter 6, where in defending the lexicographic prioritisation of Basic Access Roads I appealed to Binmore's strategic argument, based on maintenance of social stability, to defend the use of a Rawlsian normative framework. A common alternative approach in public economics has often been to take for granted that the state would be motivated to adopt such a framework simply because it meets the ideal criteria of justice. This is another instance of the appeal to a perfectly benevolent and all-powerful social planner who, as Sugden emphasises, does not and cannot exist.

Actual politicians and civil servants can only allocate road maintenance budgets on the basis of negotiating with lobbyists and political stakeholders who represent particular interests.

National budgets result from political bargaining, not rational calculations. National Treasury (2015) explains that budget policy priorities and implementation considerations are set at the Cabinet Lekgotla, following which the Ministers' Committee on the Budget sets the fiscal framework, division of revenue, and sectoral budget priorities that are taken to Cabinet for approval and finally passed in Parliament. National Treasury (2011b) stresses that the process through which choices are made about competing priorities is a political exercise "that starts with political choices about priorities and ends with political choices about which programmes and projects get funded". Sectoral budget allocations are also sensitive to inertia in the system, which is often more pronounced due to the trends set by the Medium-Term Expenditure Framework.

The road maintenance prioritisation model is therefore developed with the understanding that the budget parameters are exogenously set through political processes, then road sector policymakers exercise discretion over how the available funds are allocated among the competing road projects.

9.2 OVERVIEW OF GROWTH-ORIENTATED PRIORITISATION STRATEGY

9.2.1 The positive impact of road infrastructure on growth in South Africa

Chapter 3 combined a Cobb-Douglas linear model of output with relevant case studies to demonstrate how road infrastructure investments influence economic growth via capital accumulation and total factor productivity gains. However, to confidently proceed with an economic growth-focused road maintenance prioritisation model it is important to establish that road infrastructure investment has had a positive effect on output in South Africa and the structural relationships among the variables. In this regard, Fedderke and Bogetic (2009) use panel data from 1970 to 1993 for the South African manufacturing industry to explore: whether 19 different forms of infrastructure, including roads, have a differential impact on productivity growth; if public capital has a direct and indirect impact on productivity growth; and the impact that controlling for the potential endogeneity of infrastructure has on the estimated impact of infrastructure on the direct and indirect productivity measures.

Fedderke and Bogetic (2009) use the empirical model specified in Equation 9.1 to estimate the direct impact of infrastructure on output per employee, where *Y* is real value added of industry *i* in period *t, L* is the size of the labour force, *K* is the size of the physical capital stock, $I_{i,t}$ is a vector of 19 infrastructure components, and $X_{i,t}$ is a vector of variables relevant to labour productivity including the skills ratio of the labour force and the net export ratio of the industry to indicate the openness of the sector. All the road infrastructure measures have statistically significant and positive impacts on labour productivity, with elasticities of 2.95 for the total roads measure and 1.08 for paved roads.

$$\left(\frac{Y}{L}\right)_{i,t} = \propto + \beta_K \left(\frac{K}{L}\right)_{i,t} + \beta_I I_{i,t} + \beta_X X_{i,t} + \varepsilon_{i,t} \qquad 9.1$$

Fedderke and Bogetic (2009) estimate the indirect impact of infrastructure on total factor productivity (TFP) growth using the specification in Equation 9.2, where $SKRAT_{it}$ is the skills mix of the labour force in each manufacturing sector, NX_{it} is the net export ratio of each manufacturing sector, (R&D/Y/L) is the ratio of R&D expenditure to per capita output, $GINI_{it}$ is industry concentration, and Z_t is a vector of the various listed measures of infrastructure. Fedderke and Bogetic (2009) find that the measure for the total roads network has a strong, positive, and statistically significant impact on productivity growth, with a 1.0% increase in the road network associated with a 2.8 percentage point increase in productivity growth. Paved roads also had a strong, positive, and statistically significant impact on productivity growth, with a 1.0% increase in the paved road network between the four major metropolitan centres associated with a 4.9 percentage point increase in productivity growth.

$$TFP_{it} = \propto + \beta_{RD} \left(\frac{R\&D}{\frac{Y}{L}}\right)_{it} + \beta_{SK} SKRAT_{it} + \beta_{NX} NX_{it} + \beta_G GINI_{it} + \beta_Z Z_t + \varepsilon_{i,t} \qquad 9.2$$

9.2.2 The focus of a growth-orientated prioritisation strategy on exports

Following Fedderke and Bogetic's (2009) sectorally disaggregated evidence that confirms the potential of road infrastructure to positively impact economic growth, the next step is to determine the road user groups for which the cost function should be minimised in order to optimise economic growth. The 2012 NDP, 2010 New Growth Path, and the rolling medium term Industrial Policy Action Plans set the policy imperatives to promote national economic growth through export expansion.

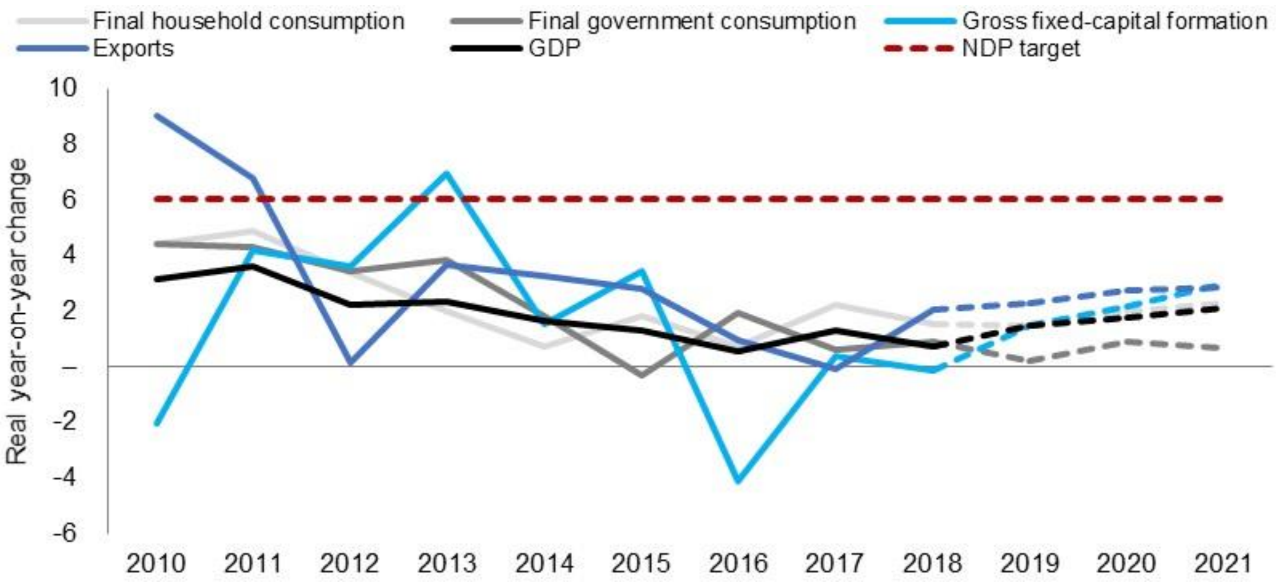
Building on the discussion in Chapter 3 about the importance of export-led growth for South Africa, the soundness of such a policy focus is supported by reference to the currently weak macroeconomic conditions in South Africa. The demand function for domestically produced goods and services is shown in Equation 9.3 and used as a framework to analyse the factors which drive the demand for goods and services produced in the South Africa economy.

$$Z = C + I + G + (X - M) \qquad 9.3$$

where *Z* is the demand for the goods and services produced in South Africa, *C* is household consumption expenditure, *I* is capital investment, *G* is government expenditure, *X* is exports of goods and services, and *M* is imports of goods and services (Giavazzi, 2014).

The NDP economic growth target of 6.0% is compared in Figure 9.1 with actual and forecast real annual growth for final household and government consumption expenditure, gross fixed-capital formation, exports, and GDP for South Africa between 2010 and 2021. All the components of demand for domestic output recorded weak growth relative to the NDP target over the past decade, with continued underperformance forecast over the medium-term.

Figure 9.1: Macroeconomic performance and projections, 2010 - 2021



Source: National Treasury, 2019.

Real annual growth in household consumption expenditure averaged 2.4% between 2010 and 2018, with the average forecast to fall to just 1.9% between 2019 and 2021. Part of the explanation for this weak growth is that real annual growth in household disposable income averaged 2.6% between 2010 and 2018. The National Treasury (2019) expressed concern about the downward pressure that weak employment growth and declining real wages and levels of household wealth have had, and are expected to have, on household consumption expenditure. Adding this information to the analysis of household debt in South Africa from Chapter 3, which stood at 71.3% of household disposable income in 2018Q2, indicates there is limited capacity for household consumption expenditure to raise economic growth from its current trajectory, which reflects a low-growth middle-income trap, to the NDP targets.

Government consumption expenditure is similarly constrained, with the National Treasury (2019) imposing a ceiling on public expenditure to offset weak revenue collection and limit the build-up of public sector debt. As a result, real annual growth in government consumption expenditure is forecast to average only 0.6% between 2019 and 2021. The government has committed to narrowing the fiscal deficit, with international ratings agencies monitoring the fiscal consolidation path and the risks posed by the increasing debt service costs and the contingent liabilities of financially distressed state-owned entities. This weak fiscal position undermines the government's ability to stimulate economic growth through public spending, implying heavier reliance on private firms over the medium to long term.

Gross fixed-capital formation experienced erratic growth between 2010 and 2018, averaging 1.5% for the period. The National Treasury forecasts average annual growth in gross fixed-capital formation to increase to 2.2% between 2019 and 2021. The South African Reserve Bank (2019) argues that higher borrowing costs and tighter lending conditions from the 2018 IFRS9 regulation and further Basel regulations in 2010, which respectively require banks to raise provisions to absorb future potential losses and to hold increased government debt, have crowded out private sector fixed investment. Growth in gross fixed-capital formation is further subdued by the generally negative Business Confidence Index since 2009 due to concerns about policy, corruption, and electricity and water supply (SACCI, 2019).

Given this sustained and forecast weakness in local drivers of economic growth, institutions such as the World Bank (2018d) and most economists support the NDP objective to prioritise export-led growth (Rangasamy, 2009; Ziramba, 2011; Cipamba Wa Cipamba, 2013; Ajmi *et* *al.,* 2015). The primary strategy to increase South Africa's economic growth is therefore to prioritise road links that boost export performance by efficiently connecting local producers with export-orientated infrastructure, specifically ports and airports.

9.2.2.1 *Consistency with international trade theory and practice*

The rationale to prioritise road links that enhance the productivity of South African firms and thereby their competitiveness in international markets by reducing the cost of doing business over distance follows neoclassical international trade theory, which argues that differences in volume and quality of infrastructure across countries may be responsible for variations in transport costs that in turn account for differences in competitiveness (Samuelson, 1954; Mundell, 1957). Firms typically convert enhanced competitiveness from lower transportation costs into higher profits or reduce their prices to raise revenue through higher export volumes and wider markets. This rationale has led other countries to place a high priority on the effect of road infrastructure on trade through freight charges and non-pecuniary costs such as speed and reliability. Examples include: the Peruvian Strategic National Export Plan 2003–2013; United Kingdom Department of Transport (1996; Eddington, 2006); European Commission's (2009) EU policy on trans-European transport networks; and 2011 United States National Export Initiative (Trade Promotion Coordinating Committee, 2011).

Behar and Venables (2011) review the role of transportation costs in international trade and show that higher transport costs deter trade. In terms of specific examples, Albarran *et al*. (2013) use a panel of Spanish manufacturing firms' to study how domestic road travel times to the nearest international border crossing and major seaport affect participation in export markets, accounting for entry costs and other firm characteristics. As in South Africa, land and sea transport are the dominant modes of merchandise transportation in Spain. Road access to international border crossings and seaports thus accounts for most of the variation in the domestic part of transportation costs in exporting. Their results indicate that domestic transport infrastructure improvements increase the probability that small and medium-sized firms' export. The finding that reduced domestic travel time to international markets improves the viability of export strategies for small firms and high-productivity non-exporters is aligned with the findings by Melitz (2003) and Bernard *et al*. (2006).

Cosar and Demir (2014) criticise transportation cost studies that do not isolate the domestic component of transportation costs for export products. Gravity-based quantitative models typically estimate bilateral trade costs as a residual after controlling for the distance between countries and other bilateral characteristics related to trade costs, whereas studies that use international shipping costs typically focus on port-to-port costs or fail to distinguish between international and intranational segments of transport costs. Cosar and Demir (2014) cite studies by Rousslang and To (1993) in the USA and Atkin and Donaldson (2012) in Ethiopia and Nigeria to demonstrate that the intranational component can account for a nonnegligible part of the overall cost of transporting goods across borders. Using data from large-scale public investment in Turkey from 2003 to 2012 that aimed to improve the quality of the road network by growing four-lane expressways from 12.0% to 35.0% of the national road stock, Cosar and Demir (2014) find that improved road infrastructure quality positively affected within-country specialization patterns and the volume and composition of regional exports, especially in time-sensitive industries.

The earthquake experienced by Chile in 2010 damaged isolated sections of the country's road network, thereby diminishing the available road infrastructure for only some exporters. Volpe Martincus and Blyde (2012) use this exogenous shock variation in the quantity and quality of road infrastructure to identify the effects of domestic road infrastructure on firms' exports. By contrasting exports among the affected and non-affected exporters whilst controlling for potential confounding factors, they find that diminished road infrastructure had a negative impact on export values and quantities. Another natural experiment is examined by Volpe Martincus *et al*. (2014), who use the persistent closing of a main bridge connecting Argentina and Uruguay due to social demonstrations to estimate the impact of increased transportation costs from rerouting and switching transport modes on trade. They estimate that a 1.0% increase in transportation costs reduced firms' exports by 6.5%, with this effect traced to smaller and fewer shipments.

Lastly, Volpe Martincus *et al*. (2017) review the effect that the 10.0% expansion in Peru's main road network between 2003 and 2010 had on local firms' exports. The roads were asymmetrically distributed across Peru, meaning that the distance travelled from production to export points and the transportation costs incurred fell for some producers while remaining constant for others. By contrasting exports in both groups of producers while controlling for potential confounding factors, they found that the road network improvements had a positive effect on firms' exports primarily through larger shipments.

9.2.2.2 *Consistency with the theory of regional development*

The road maintenance prioritisation model draws on Hirschman's (1958) theory of regional development, later revised by Hansen (1965). Hansen divides public capital into economic overhead capital (roads, sewerage, water, and utilities) and social overhead capital (health, education, and nutrition), and regions into those that are congested, intermediate, and underdeveloped. In this setting, economic growth is maximised by concentrating economic overhead capital in intermediate regions. According to this theory of regional development the economic growth effects of Tactical and Strategic Roads, which occur in the intermediate and underdeveloped regions, are maximised by prioritising roads in intermediate regions.

Rephann (1993) uses USA data to confirm that the growth potential from road development is lower in extremely underdeveloped regions compared to regions in an intermediate stage of development with low growth. When road access is a constraint on the attainment of economic opportunities then road investment can stimulate economic growth by opening up regions with growth potential. However, the relevance of this argument is limited in South Africa given the high density of the rural road network, which was shown in Chapter 2 to be roughly in line with developed countries for which Rephann's findings apply. Moreover, the development arguments have evolved to view road access as necessary but not sufficient for economic development (Huddleston and Pangotra 1990). Because road access is often not the primary constraint on the attainment of economic opportunities by households and firms in underdeveloped areas of South Africa, it is argued that in general economic growth is best promoted by prioritising roads that support higher levels of current economic activity. This ensures that the road maintenance prioritisation model supports areas of production, which may shift to areas now classified as extremely underdeveloped once other constraints to economic growth are resolved in these areas. In this way the prioritisation strategy remains responsive to changing patterns of production and economic growth potential.

9.3 COST FUNCTION APPROACH

The typical method for modelling trade flows are gravity models, which in their simplest form estimate that bilateral trade between two countries is directly correlated to their respective GDPs and inversely proportional to the distance between them (Mele and Baistrocci, 2012). More sophisticated gravity models add additional independent variables such as shared language, culture, and religion. Because distance is a determinant of trade, gravity models predict that countries trade more with countries in closer geographic proximity. However, South Africa, like other developing countries such as Brazil, is different in that it produces relatively sophisticated export products that are not intended for its geographic neighbours but rather for American, Asian, and European markets. Much of South Africa's intra-African trade is also by sea, despite the distance being longer than by road, due to the poor reliability and quality of the regional road infrastructure. The competitiveness of local firms and thereby South Africa's export volumes are thus driven by the cost of getting export products from production points to ports and airports, and by the cost of knitting together supply chains.

Accessibility to ports and airports is determined by the cost and time of transport between origin and destination, in other words the difficulty involved in travelling between locations. Banister and Berechman (2003) explain that conventional trip distribution models combine travel time and monetary costs to produce a single measure of accessibility termed 'generalised costs'. Accessibility can be calculated for a single road link or for a combination of road links that form a route between locations. Links within the network would have a different impact on accessibility were they removed from service or undermaintained to the point where only certain vehicle classes could pass. Taylor *et al.* (2006) consider a road network *G(N, E)*, where *N* is a set of *n* nodes and *E* is a set of *m* directed links. V_{ijrs} denotes the change in generalised cost of travel from node *i* to node *j* if network link e_{rs}, which connects nodes *r* and *s* is the network, failed. Associated with each link is a non-negative attribute that measures the utility of the link according to a specific link characteristic, such as distance, time, money cost, reliability, or generalised cost. Let *s[ij, G(V, E)]* be the cost of the least cost path from *i* to *j,* then:

$$V_{ijrs} = s[ij, G(N, E)] - s[ij, G(N, E - e_{rs})] \qquad 9.4$$

which, as Taylor *et al.* (2006) explain, is the difference between the least cost path with the network intact and the least cost path without the link from *r* to *s*, e_{rs}. V_{ijrs} is negative as it measures an increased cost of travel in the degraded road network, and hence the reduction in the productivity of the connected firms.

9.3.1 The general cost function model

The impact road links have on firms' productivity is explored using a cost function approach. Cost function models investigate the effect of public capital formation on economic growth and productivity, and produce shadow value parameters that indicate the cost savings from an additional public capital investment, which are regarded as returns to public investment (Banister and Berechman, 2003). Cost function models thus explain growth by showing how public infrastructure investment enables firms to reduce their average costs by reducing the use of private inputs or increasing their productivity (Banister and Berechman, 2003). The general structure of the cost function model is given by Equation 9.5:

$$C = C(\overline{w}, K_P, K_G, t, Y) \qquad 9.5$$

where *C* is the private sector's variable cost function, $\overline{w}$ is a vector of input factor prices, K_P is private capital, K_G is public capital, *t* is a time index that represents technological change, and *Y* is output. Banister and Berechman (2003) explain that the input price vector generally includes the prices of labour, private capital, public capital, materials, and energy.

9.3.2 Cost function models applied to road networks

Many road network studies have adopted a cost function approach and found evidence in support of the "public capital hypothesis", which posits that public capital raises the marginal productivity of private capital and that the provision of public capital is to some degree a prerequisite for private investment activities. The most notable study was by Seitz (1993), who applied a general Leontief cost function model to investigate how highway extensions in Germany affected the productivity of 31 private industries in the manufacturing sector. Seitz's results show that public road infrastructure investment positively contributed to firms' economic performance. Morrison and Schwartz (1996) also applied a cost function model to estimate the direct effect of public capital on productivity changes for manufacturing firms in the USA. They too found that public infrastructure investment provides a significant return to manufacturing firms and augments productivity growth.

Cohen and Morrison Paul (2004) estimate a cost-function model by maximum likelihood techniques using price and quantity data for 48 US states from 1982 to 1996 for aggregate manufacturing output and inputs and public highway infrastructure. Their model separates intra- and inter-state effects of public infrastructure and accounts for any interaction between these variables. Their model assumes that the manufacturing firms minimise short-run costs by choosing a combination of inputs for a given level of input prices, demand (output), and capacity (capital) and also technological and environmental conditions. The results indicate that public infrastructure investment lowers manufacturing costs, with an elasticity of around -0.15. The elasticity increases to -0.23 if the spillover effects across states are considered. The intra- and inter-state effects of public capital on manufacturing costs are found to grow over time. These results are aligned with Nadiri and Mamuneas (1994), who find using a translogarithmic cost function model that the elasticity of total costs with respect to public capital expansion ranged, at the time of their study, from -0.11 to -0.22 for manufacturing industries in the USA.

Another relevant study is Keeler and Ying (1988), who use a cost function approach to investigate the impact of highway investment on the cost and productivity of private trucking in the USA. Their results suggest that the highway expansion which occurred between 1950 and 1973 had a significant impact on the productivity growth of the private trucking sector.

Berndt and Hansson (1992) apply a cost function approach to test the links between public infrastructure capital and the private sector’s costs in Sweden between 1960 and 1988. The main conclusion is that public capital expansion increased private sector productivity by lowering its costs. A similar conclusion is drawn for the USA nonfinancial corporate sector by Lynde and Richmond (1992), who adopted a translog cost function to examine the impact of the stock of public capital on production costs in the private sector between 1958 to 1989. Lynde and Richmond find strong evidence of the supportive role played by public capital in the productivity of the private sector, and find that the marginal productivity of public capital is positive and that public and private capital are complements in production. In the absence of private provision of road infrastructure, neglect of the public capital stock would impede firms’ productivity and reduce the potential for economic expansion.

These studies draw two key conclusions: investment in public road infrastructure enhances private capital profitability, which in turn stimulates private capital investment and economic growth; and average investments in the stock of transportation infrastructure produce high rates of return for the economy with additional investments yielding significant marginal net benefits. Governments should thus adopt an activist strategy to road infrastructure provision as this public capital is potentially an important engine for economic development.

9.4 ROAD PROJECT EVALUATION METHODOLOGY

Banister and Berechman (2003) explain that growth-promoting road investments are carried out incrementally as individual projects are planned, approved, and executed. This project implementation process rests on a project evaluation methodology in which the primary objective is to determine the contribution of each project to economic growth. The common project evaluation approach is BCA.

9.4.1 Constraints on the application of BCA

The World Bank (2001) book, *Economic Analysis of Investment Operations*, starts by noting that although BCA provides a well-developed and straightforward conceptual framework for measuring the benefits of transport projects, the data requirements are intensive. The basic BCA equation is shown in Equation 9.6.

$$Net\ benefits = Total\ benefits - Total\ costs \qquad 9.6$$

To conduct a full BCA all the project costs and benefits must be identified and monetised, following which the project costs are subtracted from the benefits to obtain the net benefits of the project. This task of obtaining accurate estimates for all the costs and benefits of a road project is further complicated by the fact that the road investment prioritisation model is intended to be a network-level decision tool.

Road projects are typically associated with four main benefits: reduction of vehicle operating costs; reduction of road accidents; passenger and freight time savings; and environmental impacts (World Bank, 2001). Of these factors, the municipal and provincial road authorities only have sufficient data to approximately estimate the benefits from a reduction of vehicle operating costs and a reduction of road accidents.

Although SANRAL (2018b) attempts to account for passenger time savings in their national HDM-4 setup, this exercise faces two major criticisms. Firstly, the provincial and municipal road authorities lack data regarding the vehicle occupancy rates as well as the purpose of road trips. Secondly, the respective hourly rates of R80.0 and R40.0 assigned to passengers for work and non-work time do not reflect regional labour market characteristics or the time preference of passengers. While both criticisms can be addressed through additional data collection and research, these exercises are resource intensive and are yet to be included in the sector's medium-term plan which currently runs until 2023.

In terms of environmental impacts, Sections 7.4.1, 7.4.2, and 7.4.3 respectively noted some of the environmental impacts of road projects in terms of dust generation, biodiversity, and water consumption. Additional environmental impacts of road projects include pollution from roadworks and vehicle emissions. While some of these impacts can be monetised at the network level, many are region specific and require further research to enable accurate estimates. As concluded in Chapter 7, data restrictions preclude the accurate estimation of environmental impacts for a network-level BCA. Future research should address this gap.

The provincial and municipal road authorities are thus confined to partial BCA. Any attempt to perform full BCA at the network-level would be inaccurate until the data are available to monetise the economic impact of road projects in terms of the passenger time savings and environmental impacts. This situation reflects the general conditions cited by Boardman *et al.* (2005) that motivate the use of CEA: analysts are unwilling or unable to monetise the most important impacts of a project; analysts may recognise that a particular effectiveness measure does not capture all of the benefits of each alternative, but the outstanding benefits are difficult to monetise; and analysts may be dealing with intermediate goods whose linkage to preferences is not clear, such as the transportation to a place of interest like a school.

9.4.2 Positive argument in support of CEA

In addition to the defensive arguments in Section 9.4.1, which reject the application of BCA in this instance due to practical limitations and promote CEA as the second-best alternative, there is another, positive line of argument developed by Ross (2021) that supports CEA as the first-best alternative for the road maintenance prioritisation model. Ross (2021) identifies an intrinsic problem with BCA, wherein its Walrasian approach leads incrementally towards general equilibrium (GE) analysis. While GE modelling is appropriate for certain problems, such as evaluating a comprehensive international trade deal because any perspective short of that implies arbitrary disregard of some legitimate interests, it is not suitable in this case as road planners in South Africa, and in fact most countries, make their investment decisions in a context where foreclosure of ramifying effects has been massively foreclosed by political and institutional background processes. Although some theorists might be sceptical about ring-fencing such political and institutional constraints, there is surely an important place in the policy assessment ecology for perspectives that take them fully seriously, especially for practical studies like this thesis. Once political and institutional constraints on road planners are considered, their focus shifts from maximising the NPV of road projects, for which BCA is best suited, to efficiently allocating the fixed budget among alternative projects based on the investment priorities, for which CEA is best suited.

According to the discussions in Sections 9.1 and 9.2, two additional factors motivate the application of CEA for the prioritisation model. Firstly, the focus of CEA on one effectiveness measure is appropriate as the economic growth objective is confined to export promotion. Andres *et al.* (2015) confirm that CEA is well suited for project prioritisation when there is a single well-defined outcome like promoting economic growth through exports. However, this motivation only applies to countries like South Africa with a low level of internal demand. Secondly, the focus of the prioritisation model on Tactical Roads removes the congestion issues associated with urban road networks.

Given the arguments in Sections 9.4.1 and 9.4.2, CEA is supported as a method to evaluate and prioritise projects by agencies such as the World Bank (2010), European Investment Bank (2013), and Asian Development Bank (2017). Noteworthy applications of CEA in the transport sector include: the Institute for Transport Studies (2003); the Texas Department of Transportation (2003); and the Illinois Center for Transportation (2010).

9.4.3 CEA prioritisation model and empirical strategy

Banister and Berechman (2003) explain that, like BCA, the objective behind CEA is to select a project alternative that generates the greatest amount of output given the investment. The two methods follow a similar process except that CEA measures output in real rather than monetised units, which means that CEA is unable to guarantee that a project's benefits exceed its cost. While it is obviously important to determine the NPV of each road project, it is necessary to reiterate that the primary objective of the prioritisation model is to optimally allocate a fixed road maintenance budget. In this regard, CEA generates an index of output over cost for different road projects that can be applied to select the most efficient road maintenance project or set of maintenance projects given the available budget. Incidentally, it is unlikely that the prioritisation model will schedule road projects with a negative NPV for maintenance given the relatively high number of economically important roads compared to the high degree of prioritisation necessitated by the maintenance backlog in Chapter 4.

To ensure expenditure efficiency the effectiveness measure should reflect the investment objective to promote economic growth through the movement of export freight. Effectiveness is therefore measured by the number of export-related heavy vehicle-km on a road as this is the best available proxy for the volume of export freight. The flow of export freight traffic represents the usage of the road network and the potential effect of a service impairment or disruption on trade were transport on a road link affected by non-prioritised maintenance.

Because CEA does not monetise project benefits two metrics are required: the effectiveness measure and monetised costs. Costs are recorded as the financial cost of a project, which is standard practice when CEA is conducted for a government department (Boardman *et al*., 2005). The ratio of the metrics can be expressed as a cost-effectiveness ratio (CE ratio) as shown in Equation 9.7, which is the cost (*C*) of an alternative project divided by the measure of its effectiveness (*E*), or as an effectiveness-cost ratio (EC ratio), which is the effectiveness measure of an alternative project divided by its cost. Analysts typically use the CE ratio and prioritise projects with the lowest ratios.

$$CE_i = \frac{C_i}{E_i} \qquad 9.7$$

Costs and effectiveness must be measured incrementally to indicate expenditure efficiency. Boardman *et al*. (2005) demonstrate this by considering the example of two projects, *i* and *j*. The cost-effectiveness ratio of project *i* relative to project *j*, CE_{ij}, is given by the formula:

$$CE_{ij} = \frac{C_i - C_j}{E_i - E_j} \qquad 9.8$$

where C_i is the cost of alternative *i*, C_j is the cost of alternative *j*, E_i is the effectiveness units produced by alternative *i*, and E_j is the effectiveness units produced by alternative *j*. The comparison alternative, *j*, is a scenario where no project is undertaken and the road finally becomes impassable. While this alternative may be an unrealistic outcome, at least over the short term, this benchmark is necessary to estimate the average CE ratio. Once a preferred project is selected it is used as the comparison alternative to calculate incremental CE ratios.

However, because CE ratios measure technical efficiency they ignore scale effects. One implication of this oversight is that projects that produce small impacts at a relatively low unit cost will be prioritised above projects that produce larger impacts but at a higher unit cost. A common practice to mitigate the concern that scale differences among alternative projects may distort choice is to impose a constraint. This constraint could be a minimum acceptable level of effectiveness, denoted as $\overline{E}$, or a maximum acceptable cost, denoted as $\overline{C}$. The latter constraint is suited to the South African context where a budget constraint is present. If a maximum cost is specified then the project that supports the highest number of heavy vehicle-km might be selected, subject to the cost constraint:

$$\begin{array}{c}\text{Maximise } E_i \\ \text{Subject to } C_i \leq \overline{C}\end{array} \qquad 9.9$$

Boardman *et al*. (2005) note that this rule ignores incremental cost savings, meaning that cost savings beyond $\overline{C}$ are not valued. However, it is possible to select the project that most cost-effectively meets the imposed cost constraint, as illustrated by Formula 9.10. This rule places some weight on the incremental cost savings and is therefore more likely to result in the selection of a project with less than the maximum cost.

$$\begin{array}{c}\text{Minimise } CE_i \\ \text{Subject to } C_i \leq \overline{C}\end{array} \qquad 9.10$$

9.4.4 Limitations of the CEA prioritisation model

Although the prioritisation model has appeal in the simple and pragmatic way it prioritises the maintenance of economic growth-promoting road infrastructure, the approach also faces limitations. The first notable limitation of the prioritisation model is that it overlooks the impact road projects might have in terms of generated and diverted road traffic. This oversight could result in a situation where the model assigns low priority to poor condition roads with low volumes of heavy vehicle traffic, irrespective of the potential for these roads to attract enough heavy vehicle traffic once repaired to prove viable priorities. This point builds on Section 9.2.2.2, wherein it was noted that the prioritisation model promotes economic growth by favouring established trade routes and intermediate regions. Although the road maintenance prioritisation model supports higher levels of current economic activity, it is able to respond to changes in production patterns should other constraints to economic growth be resolved.

Secondly, the prioritisation model is based on a biased index of transportation services as the effectiveness measure is focused on heavy vehicle traffic. But light vehicle traffic, which does not feature in the effectiveness measure, may lower the financial and time burden of transport for workers and thus improve the competitiveness of export producers in the area.

Thirdly, the prioritisation model overlooks any negative externalities from a policy to maintain roads that promote export activity. This oversight of negative externalities should not be interpreted as endorsing a policy to increase exports at all costs. At some future point in time, if South African export promotion policy succeeds, it will reach a point of diminishing and ultimately negative returns.

9.5 EXAMPLE

The road maintenance prioritisation model is piloted on a provincial road network to test and practically demonstrate the methodology. The Mpumalanga provincial road network was chosen for the case study given the relatively extensive data availability in the province. GIS based asset management data per road link is published by the Mpumalanga Department of Public Works, Roads and Transport (DPWRT) (2019a) and includes: road surface; road classification; road width; road condition; Annual Average Daily Traffic (AADT) per vehicle class; climate; and terrain. The analysis aggregates export products and products for domestic consumption due to a lack of freight cargo data. While this oversight means that the prioritised road network is not as precise at it could be, with domestic freight acting as a noise variable, the flow of export products can be disaggregated by officials once a more comprehensive freight databank becomes available.

9.5.1 Empirical strategy

The existing RAMS should remain the primary source for the engineering and road network data. The road deterioration trends, works standards, roadwork unit costs, works and road user effects, and project timing should be set based on the inbuilt models within the RAMS. Where RAMS are not available, which is the case for many municipal road authorities, the National Treasury's (2018a) Road Network Cost Model can be applied with road network condition and traffic data. This latter empirical strategy is demonstrated in this case study.

The methodology to estimate the cost of the required maintenance work for each road link follows the approach applied in Chapter 4 to estimate the road maintenance backlog. The 2016 asset information is sufficiently detailed to categorise the 3 119 road links into 300 general maintenance categories. These maintenance categories are determined according to the following set of road characteristics: road surface (gravel or surfaced); traffic volume (low, low-medium, medium, medium-high, or high AADT); climate (wet or dry); terrain (flat, rolling, or mountainous); and Visual Condition Index (VCI) or Visual Gravel Index (VGI) (very poor, poor, fair, good, or very good). Each road category is assigned a maintenance activity based on COTO's (1996) TRH 22 condition index trigger method. The maintenance activities are then matched with unit costs from the National Treasury's (2018a) Road Network Cost Model, which uses the same categorisation system, to estimate the cost of the maintenance required by each road link. These disaggregated maintenance cost estimates are the best approximation in the absence of link specific roadwork feasibility studies.

The second step is to combine the estimated maintenance costs with AADT data to generate CE ratios for the road links. As discussed in Section 9.4.3, the effectiveness measure is set as the number of heavy vehicle-km. The road links are ordered in descending order of their

CE ratios, meaning that the roads higher in the prioritisation schedule support the greatest number of heavy vehicle-km for the given investment.

The CE-based prioritisation schedule is assessed in relation to the available budget, which was recorded at R1.5 billion in 2017/18, to determine the potential extent of the funded road maintenance activities. Given an average VCI and VGI of 57.0% and 42.0%, respectively, the available 2017/18 budget covers 11.4% of the estimated road maintenance demands. High importance therefore attaches to the prioritisation schedule.

9.5.2 Contextual economic and freight information for Mpumalanga province

With a surface area of 76 495 km^2 and population of 4.5 million people in 2018, Mpumalanga has a population density of 59.1 people per km^2 (Statistics South Africa, 2018e). The main agglomeration centres include the secondary cities of Nelspruit, Witbank, Middelburg, and Secunda and the towns of Standerton, Piet Retief, Malelane, Ermelo, Barberton and Sabie. Mpumalanga is bordered by Gauteng province in the west and Swaziland and Mozambique in the east. The Maputo Development Corridor links Mpumalanga with Gauteng and the deep water ports of Maputo and Matola in Mozambique.

Table 9.1: Mpumalanga GDP by activity, 2017

Industry	Current prices (R millions)	Percentage contribution to	
		National industry output	Provincial GDP
Primary industries			
Agriculture, forestry and fishing	9 702	*8.8%*	*2.8%*
Mining and quarrying	73 987	*21.5%*	*21.2%*
Secondary industries			
Manufacturing	41 654	*7.5%*	*11.9%*
Electricity, gas and water	23 855	*15.1%*	*6.8%*
Construction	9 483	*5.8%*	*2.7%*
Tertiary industries			
Trade, catering and accommodation	45 827	*7.3%*	*13.1%*
Transport, storage and communication	20 749	*5.1%*	*5.9%*
Finance, real estate and business services	36 615	*4.4%*	*10.5%*
Personal services	12 231	*5.0%*	*3.5%*

General government services	38 920	*5.3%*	*11.2%*
Taxes less subsidies on products	**35 965**		**10.3%**
Total GDP at market prices	**348 987**		**100.0%**

Source: Statistics South Africa, 2019b.

Mpumalanga was the 5th largest of South Africa's 9 provincial economies in 2017. Table 9.1 shows that the provincial economy contributed R349.0 billion to GDP in 2017, which equates to 7.5% of national GDP. The real economy comprises the mining, agriculture, construction, and manufacturing industries and made up R134.8 billion or 38.6% of provincial output in 2017. The mining industry made the largest contribution of R74.0 billion to provincial output, equating to 21.5% of total national mining output. While much of this mining output was coal for the Eskom power plants located in the province or export from Richards Bay, significant volumes of gold, iron ore, and platinum were produced for export. The manufacturing sector mainly consists of stainless steel, chemicals, paper and pulp, and wood and mining products and contributed R41.7 billion to provincial output, which equates to 7.5% of total national manufacturing output. The provincial land area comprised 21.1% arable land, 39.6% grazing land, and 6.7% forestry. 90.1% of these combined areas were commercially operated and produced R9.7 billion in agricultural output, equating to 8.8% of total national agricultural output (Department of Agriculture, Forestry and Fisheries, 2018). As a percentage of total national commercial production in 2017, Mpumalanga produced: 20.0% of maize; 41.2% of sorghum; 42.0% of soya beans; 12.4% of dry beans; 10.0% of cattle; 7.0% of sheep; 7.9% of pigs; 20.3% of poultry; and 5.3% of wool; and significant volumes of sugar, potatoes, and citrus and subtropical fruit, (Department of Agriculture, Forestry and Fisheries, 2017).

Table 9.2 shows the tonnes transported on surveyed road freight routes in Mpumalanga in 2010. The Mpumalanga DPWRT (2019b) explain that the data, which were collected for a 12-hour period from 6am to 6pm per survey point, indicate route activity. While the volume of freight appears relatively low on some routes, the total tonnes on all the sampled roads are large enough to represent a significant contribution to trade. Coupled with the fact that 87.0% of total freight in 2008 was transported by road, this limited sample suggests that road transport is a vital component of trade in the province (Mpumalanga DPWRT, 2019b).

Table 9.2: Surveyed total tonnes per route, 2010

Route	Section	Total tonnes per survey point per 12-hour period
N4	Nelspruit - Komatipoort	34 198
R50	Leandra - Standerton	25 615
N11	Ermelo - Hendrina	24 716
N17	Leandra - Secunda	23 899
R39	Standerton - Bethal	20 143
R39	Standerton - Margenzon	19 167
N2	Ermelo - Piet Rietif	17 783
N4	Middelburg - Nelspruit	17 460
R38	Badplass - Barberton	15 318
R545	Ogies - Bethal	14 825
N4	Witbank - Pretoria	14 574
R33	Piet Rietif - Commondale	12 523
N11	Volksrust - Ermelo	12 409
N11	Middelburg - Groblersdal	8 662
N4	Komatipoort - Lebombo Border	7 762
R33	Warburton - Amsterdam	7 387
R571	Komatipoort - Mananga	7 375
R36	Carolina - Watervalboven	7 360
R23	Standerton - Volksrust	7 286
R40	Barberton - Nelspruit	6 536
R570	Jeppes Reef - Malelane	6 085
R540	Belfast - Lydenburg	6 082
N4	Barberton - Kaapmuiden	5 956
R37	Sabie - Lyndenburg	4 174
N17	Lochiel - Oshoek	3 796
R537	Sabie - Nelspruit	3 489
R36	Ohrigstad - Lydenburg	3 443
R38	Carolina - Hendrina	2 991

Source: Mpumalanga Department of Public Words, Roads and Transport, 2019b.

Table 9.3 shows road freight origination and destination data collected by the Mpumalanga DPWRT (2019b) in 2010. The data were collected at traffic control centres and weighbridges in Mpumalanga along the N4, N11, and N17. In line with the large production base detailed in Table 9.1, the majority of road freight, 60.2%, originated in Mpumalanga. 4.8% of the road freight was for export to Mozambique, Swaziland, Lesotho, and Botswana. It is likely that a large proportion of the 10.8% of freight to KwaZulu-Natal is also destined for export via the Richards Bay and Durban ports.

Table 9.3: Mpumalanga road freight origination and destination survey, 2010

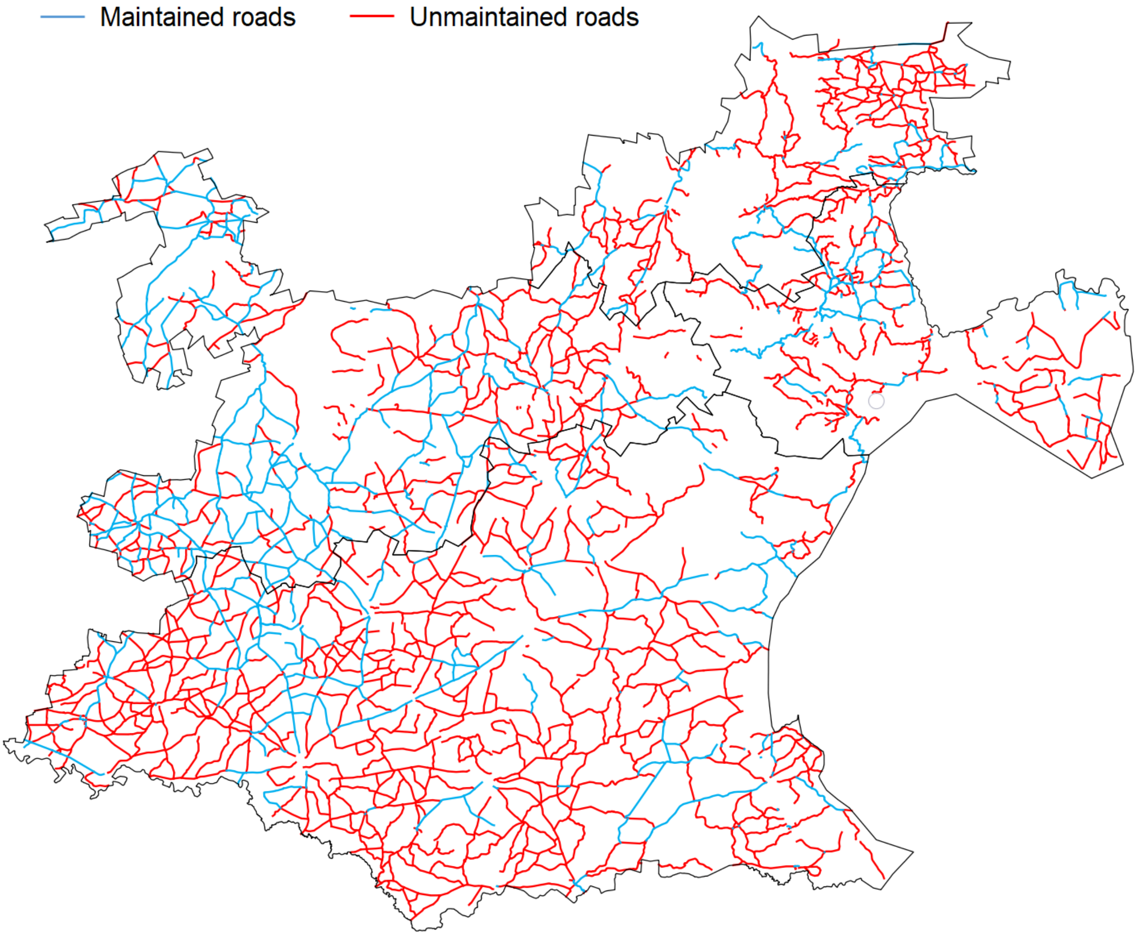
Area	Percentage of freight origination	Percentage of freight destination
Mpumalanga	60.2%	58.2%
Gauteng	19.9%	16.5%
KwaZulu-Natal	5.1%	10.8%
North West	5.3%	3.4%
Mozambique	0.9%	3.2%
Western Cape	0.2%	3.2%
Limpopo	1.9%	1.3%
Eastern Cape	0.0%	1.1%
Swaziland	1.7%	0.8%
Lesotho	2.1%	0.6%
Free State	0.9%	0.4%
Botswana	0.6%	0.2%
Northern Cape	1.1%	0.2%

Source: Mpumalanga Department of Public Words, Roads and Transport, 2019b.

9.5.3 The extent of the prioritised road maintenance schedule

The Mpumalanga provincial road network included 13 875 km of proclaimed roads in 2016. Figure 9.2 indicates which roads the model prioritised for maintenance attention in 2017/18. Although the available budget covers only 11.4% of the estimated maintenance backlog, the model ensures that 3 719 km of road, or 26.8% of the total road network, is maintained. This positive outcome is possible as the model promotes a preventative maintenance strategy, as followed by SANRAL (2013), with 73.6% of the prioritised roads set to receive routine or periodic maintenance. In comparison, the Mpumalanga DPWRT (2018) allocated 48.8% of actual expenditure in 2017/18 to maintenance works. The heavier emphasis placed by the DPWRT on rehabilitation work may have been prompted by the strategic objective to reduce the proportion of roads in poor and very poor condition from 40.0% to 29.0%, however, this worst-first approach is not aligned with the objective to maximise support for freight flows.

Figure 9.2: Prioritised road maintenance schedule



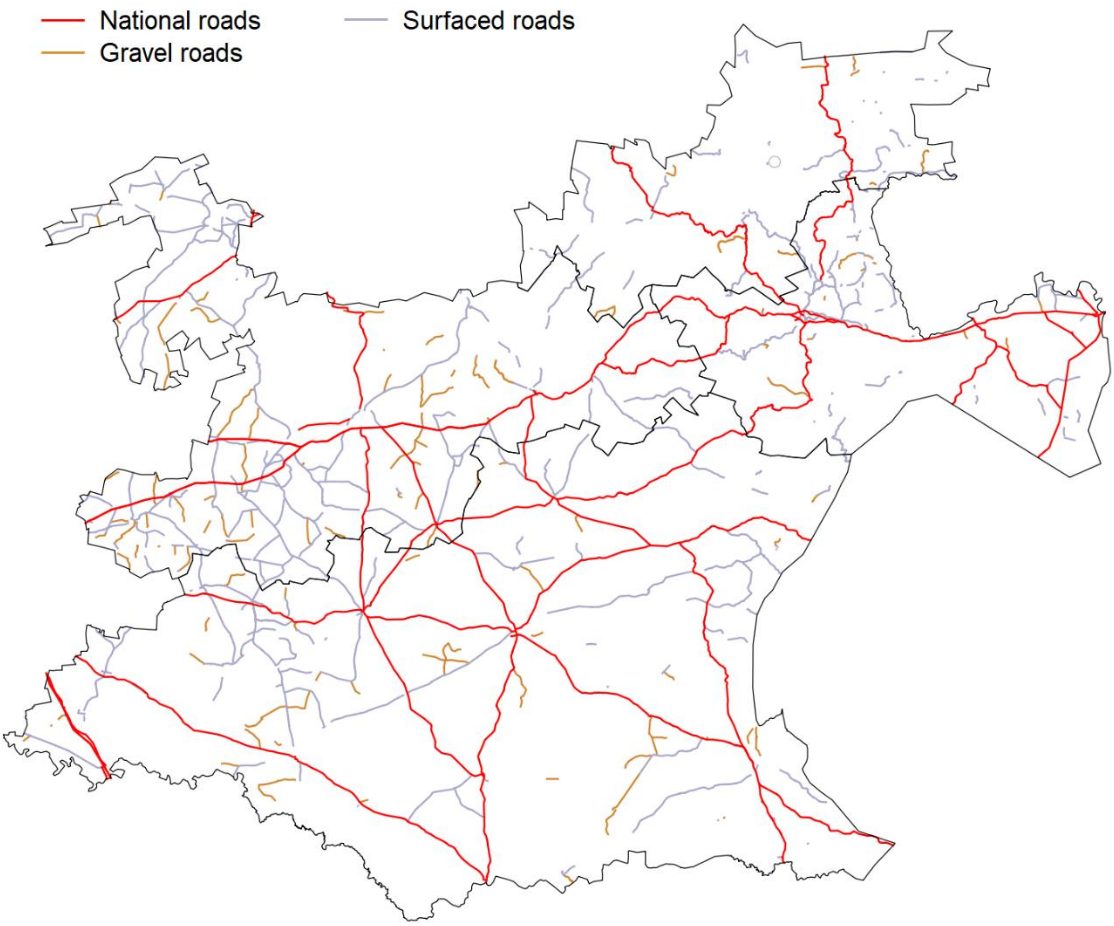
Source: Own calculations.

With the available budget the Mpumalanga DPWRT (2018) achieved the following results in 2017/18: 124 km of surfaced roads rehabilitated and 1 193 km resealed; 497 km regravelled; and 36 481 km bladed. In relation to these outcomes, the maintenance schedule proposed by the model would have enabled the DPWRT to extend the length of rehabilitated surfaced roads by 27.4% and the length of surfaced roads resealed by 90.6%. The trade-offs for these additional works on surfaced roads are a 24.2% reduction in regravelling and 8.2% reduction in blade-km. Because this trade off is informed by CE ratios it allows the DPWRT to support higher freight volumes with the available budget, although the exact vehicle-km are unknown without information about the specific routes that were maintained by the DPWRT. The prioritised roads facilitate 561.0 million annual heavy vehicle-km, which is 73.3% of the total heavy vehicle-km travelled on the network. The prioritised road maintenance schedule thus supports a high proportion of the trade flows in the province.

9.5.4 The prioritised road maintenance schedule according to surface type

The provincial road network comprised 5 459 km of surfaced roads and 8 396 km of gravel roads. The Mpumalanga DPWRT (2016) emphasises the economic priority of the surfaced road network as it carries 80.8% of the total heavy vehicle-km. The prioritised maintenance schedule generated by the model reflects this fact by accommodating 52.8% of the surfaced road network compared to 10.0% of the gravel road network, with the first gravel road ranked as only the 482nd work item. However, high variation in freight traffic within the gravel road network means that some gravel roads carry more freight traffic than surfaced roads. While the average heavy vehicle composition of AADT is 19.6% for the provincial surfaced road network and 20.6% for the provincial gravel road network, the heavy vehicle composition of AADT on prioritised roads averages 21.5% for surfaced roads and 30.4% for gravel roads. This indicates that the model has prioritised roads with higher proportions of freight traffic, especially among gravel roads to compensate for the typically lower traffic volumes.

Figure 9.3: Prioritised road maintenance schedule according to surface type



Source: Own calculations.

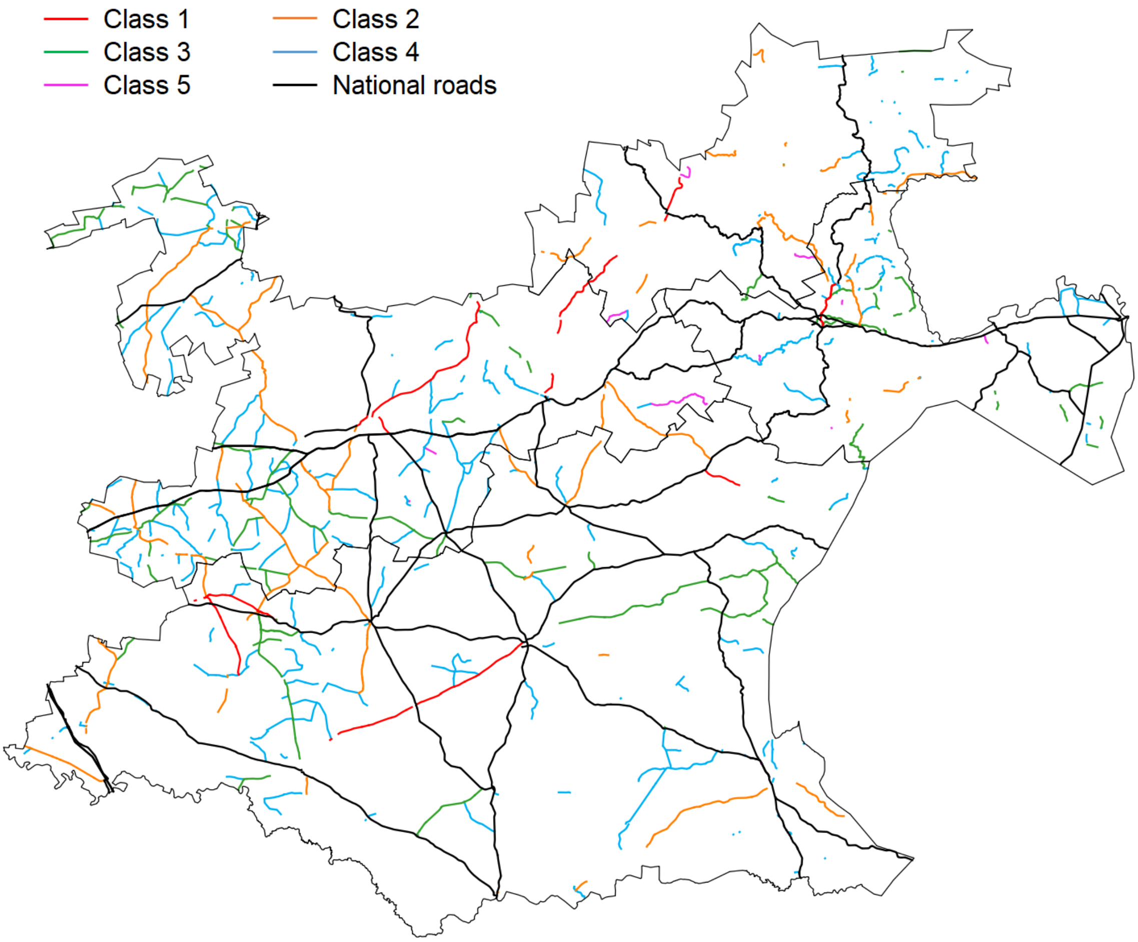
Figure 9.3 illustrates the distribution of prioritised roads between surfaced and gravel roads. 61.2% of the prioritised roads are surfaced roads and 38.8% are gravel roads. An alternative decision to forego the maintenance of the prioritised gravel roads in favour of the next most important surfaced roads, which has occurred in provinces such as the Free State, would reduce the supported annual heavy vehicle-km by 59.4 million km.

9.5.5 The prioritised road maintenance schedule according to functional class

As discussed in Chapter 5, the TRH 26 functional road classification system is an inadequate prioritisation methodology to ensure that the maintained road network makes the maximum contribution to economic growth. However, the Mpumalanga Provincial DPWRT (2016) state that: "During the needs analysis of the provincial road network, the optimisation process places emphasis on the higher class roads (1 through 3)". It is likely that most, if not all the provincial road authorities place a similar reliance on functional road classes to inform their road maintenance schedules. The National Treasury (2018a) confirm that this practice was at least followed by the Free State Department of Police, Roads and Transport and Northern Cape Department of Roads and Public Works. The Western Cape Department of Transport and Public Works' (2017) Road Asset Management Plan also assigns each of the functional road classes a different level of service and degree of maintenance intensity.

While the prioritised maintenance schedule generated by the model is sensitive to the fact that roads in functional classes 1 through 3 typically support higher volumes of freight traffic, the prioritisation results shown in Figure 9.4 and Table 9.4 also confirm that the functional classification system is an imprecise basis for an economic growth-orientated prioritisation schedule. The model prioritised 318 km class 1, 920 km class 2, 839 km class 3, 1 577 km class 4, and 65 km class 5 roads for maintenance in 2017/18. The prioritised class 4 and 5 roads were selected over 33.1%, 44.2%, and 52.0% of class 1,2, and 3 roads, respectively. Prioritising these class 4 and 5 roads rather than prioritising roads in descending order of functional classes allows the road maintenance schedule to support an extra 272.6 million annual heavy vehicle-km. The ratio in Table 9.4 between the percentage of prioritised roads in each class and the percentage of heavy vehicle-km supported indicates that the model prioritised the maintenance of roads with the highest marginal return in heavy vehicle-km.

Figure 9.4: Prioritised road maintenance schedule according to functional road classes



Source: Own calculations.

Table 9.4: Road network and prioritisation schedule according to functional road classification

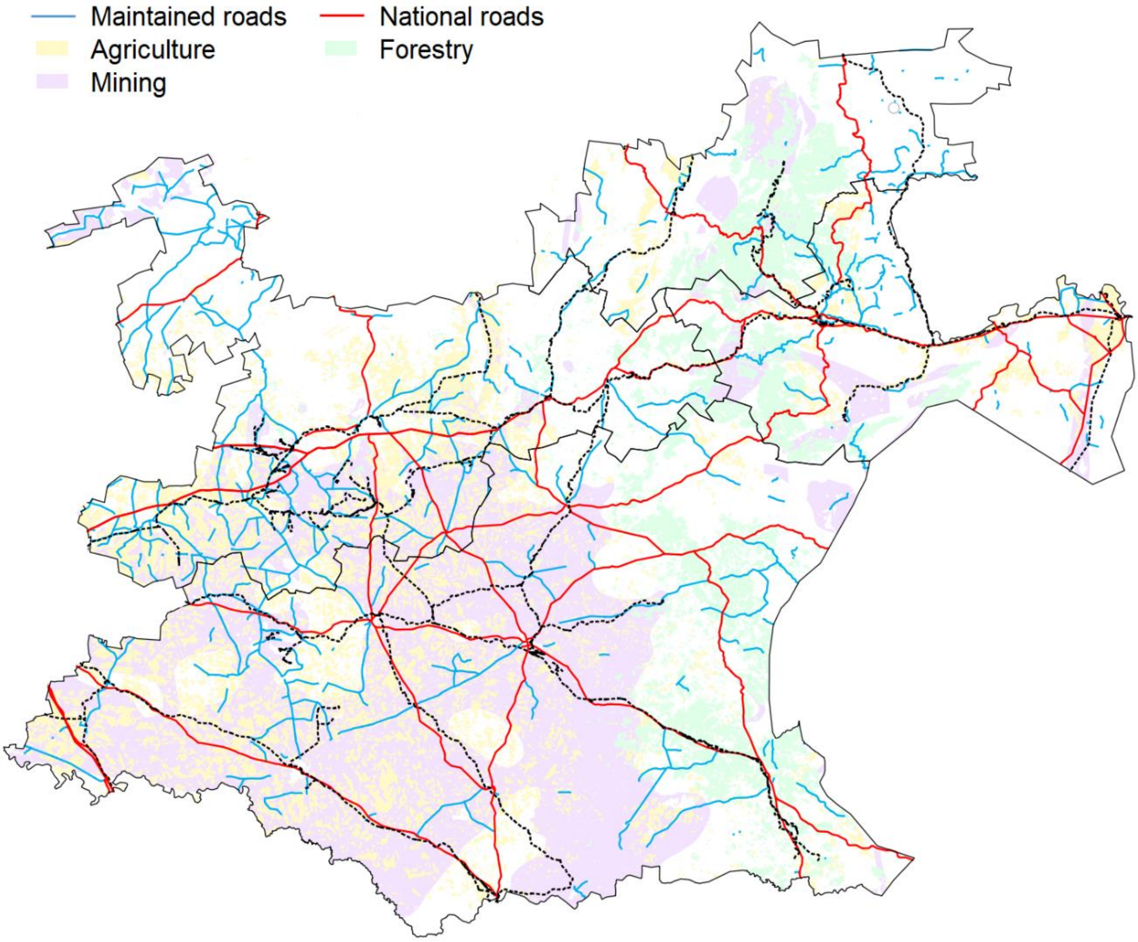
	Class 1	Class 2	Class 3	Class 4	Class 5
Total length	475 km	1 650 km	1 748 km	9 556 km	425 km
Prioritised length	318 km	920 km	839 km	1 577 km	65 km
% prioritised	*66.9%*	*55.8%*	*48.0%*	*16.5%*	*15.4%*
Total heavy vehicle-km	93 892 296	222 163 263	160 314 893	283 465 360	5 690 879
Prioritised heavy vehicle-km	78 654 738	167 872 914	126 189 800	185 682 796	2 550 344
% prioritised	*83.8%*	*75.6%*	*78.7%*	*65.5%*	*44.8%*

Source: Mpumalanga Provincial Department of Public Works, Roads and Transport, 2019; Own calculations.

9.5.6 The prioritised road maintenance schedule compared to land use

Figure 9.5 compares the road maintenance prioritisation schedule with land use patterns, which are a proxy for the areas of production. The Mpumalanga DPWRT (2016) also publish spatial data on land use, specifically: agriculture; forestry; and mining. Mining is a dominant activity in the province, with 14.0% of provincial roads classified as coal haul roads. These coal haul roads, which carry 43.0% of the network's heavy vehicle traffic, are mostly in the north- and south-west regions and feature prominently in the prioritisation schedule. The road network provides less support to the gold and iron ore mines in the north of the province as these are largely serviced by the rail network. The road network also supports the timber sector in the east, sub-tropical fruit production in the north-east, and vegetable and summer grain production in the centre and west of the province. Together with national roads, the prioritised roads form strategic transport links connecting many production zones.

Figure 9.5: Prioritised road maintenance schedule in relation to land use patterns

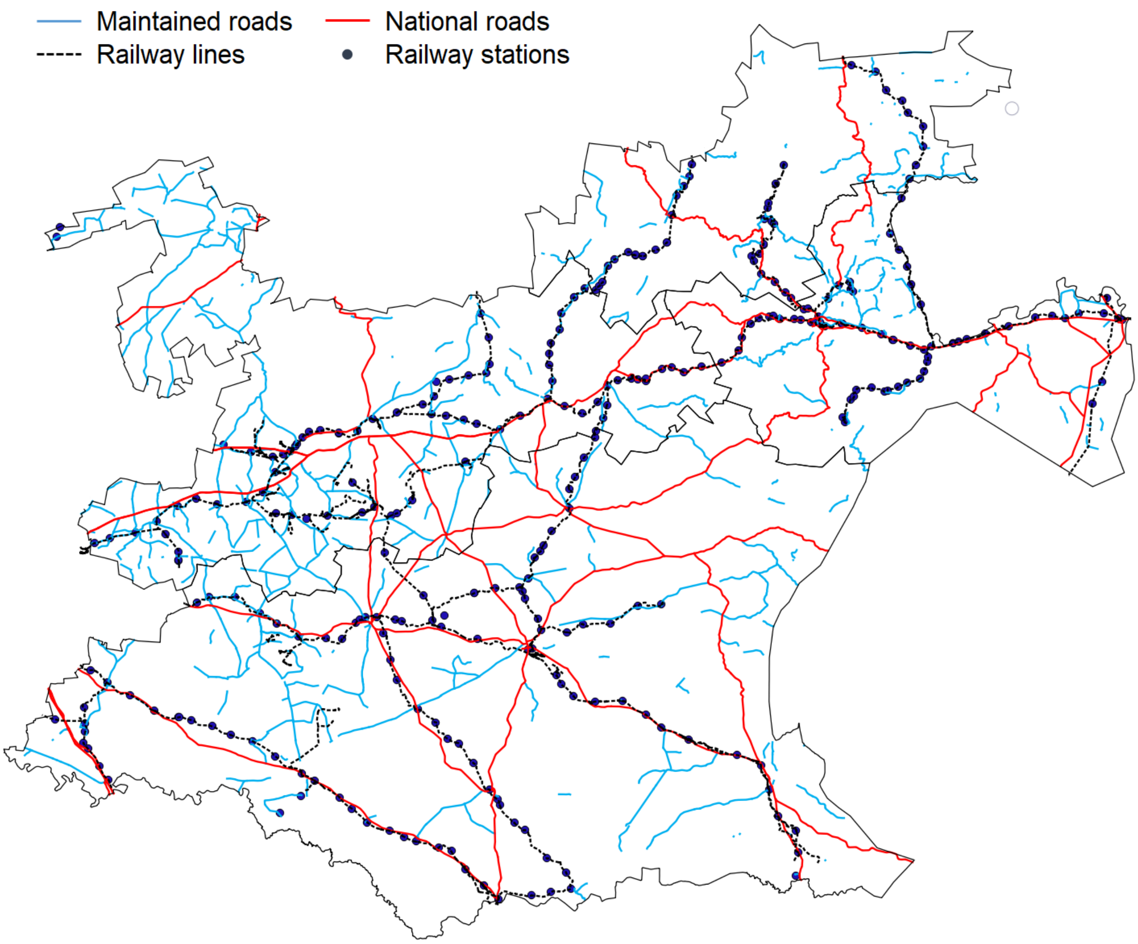


Source: Own calculations.

9.5.7 The prioritised road maintenance schedule compared to the rail network

Although there has been a significant shift from rail to road freight, as discussed in Chapter 2, it remains important that the prioritised road network facilitates the movement of relevant products from point of origin to the appropriate railway station. The Mpumalanga DPWRT (2019b) explain that the rail network in Mpumalanga carries the highest volume of traffic of all provinces in South Africa and is therefore vital to the movement of freight, especially coal, chrome and ferrochrome, forestry products, chemicals and liquid fuels, and various grains.

Figure 9.6: Prioritised road maintenance schedule in relation to national roads and railways



Source: Own calculations.

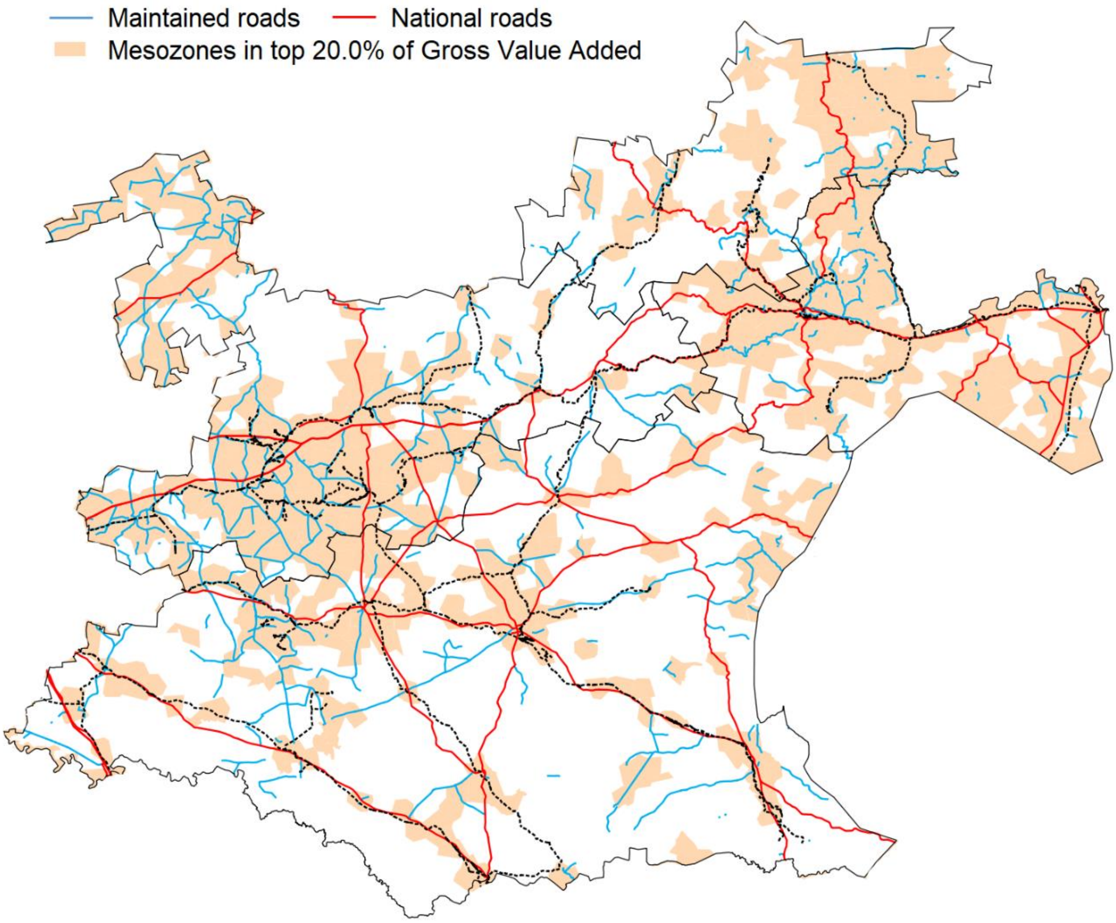
Figure 9.6 shows that the prioritised road network forms connections with railway stations across the province. The prioritised road network connects the coal mines in the south-west, which account for most of the province's mining exports, to the Balfour North to Volksrust section of the Gauteng to Durban mainline and several areas to the Maputo Development

Corridor. In addition to other key road to railway connections, the prioritised roads connect chrome mines to the Steelpoort branch, iron ore mines to the Roossenekal branch, and forestry producers to the Graskop, Barberton, and Lothair branches.

9.5.8 The prioritised road maintenance schedule in relation to GVA

The last verification of the road maintenance prioritisation model is to compare the prioritised road network with GVA. Figure 9.7 overlays prioritised roads with mesozones in the highest GVA quintile (CSIR, 2017). While the budget shortfall means that roads in certain areas are necessarily excluded from the maintenance schedule, there is extensive overlap between high productivity areas and prioritised roads. In fact, almost all highly productive mesozones are connected by either one or a combination of provincial roads, national roads, or railways. The road maintenance prioritisation schedule therefore ensures that as many areas as possible with high economic value are connected to other firms and freight routes.

Figure 9.7: Prioritised road maintenance schedule in relation to mesozones with high GVA



Source: Own calculations.

9.6 CONCLUSION

Before provincial and municipal road authorities prioritise their Tactical Road Networks, their primary and secondary objectives are to maintain Basic Access Roads and Strategic Roads, respectively. This road maintenance prioritisation model provides road authorities with a tool to help ensure that the remainder of their exogenously determined road maintenance budget makes the maximum contribution to potential economic growth. This outcome is achieved by prioritising road maintenance projects that cost-effectively support the highest volumes of freight, thereby enhancing productivity for the largest number of producers and products. This should in turn improve the international competitiveness of South African firms currently exporting, as per the NDP objectives, and encourage other firms to begin exporting.

Should sufficient freight origin-destination and input-output data became available, which is at best a medium- to long-term prospect, then road authorities could follow the example of Souleyrette *et al.* (1998), Brogan *et al.* (2001), and Schroeder *et al.* (2012) and disaggregate freight cargo to better focus the effectiveness measure on export freight. Another potential extension to the application of the prioritisation model is to weight the effectiveness measure according to key variables, such as the value of freight and labour-intensity of the associated sector. However, three developments are necessary before the road authorities can extend the application of the prioritisation model: Firstly, authorities must have access to a detailed and updated freight databank. This databank must extend beyond national roads, which is the current scope of the National Freight Flow Model, and include the type, volume, origin, and destination of freight (Havenga and Pienaar, 2012). Secondly, the AADT data must disaggregate heavy vehicles into short, medium, and long trucks and according to number of axles. Thirdly, accurate regional input-output data must be added to the national social accounting matrix and the sub-national derivatives. Following these developments, analysts can make relatively straightforward extensions to the effectiveness measure to improve the alignment of the road maintenance prioritisation schedule with the NDP objective to support higher value, export freight produced in relatively labour-intensive industries.

Only once road authorities achieve these advanced stages of data availability and address the research gaps for BCA listed in Section 9.4.1 will they be positioned to extend the road maintenance prioritisation model beyond CEA to include full BCA and computable general equilibrium (CGE) models. In this respect, Robson *et al.* (2018) provide a detailed review of the application of CGE models to investment appraisal in the transportation sector and the ability of CGE models to evaluate the broader economic impacts of road expenditures. Road managers and researchers must monitor the progress of data collection and studies in the sector to determine when the provincial and municipal road authorities can accommodate these respective shifts, and once ready to assist with the transition.

The intention is not for this road maintenance prioritisation model to replace the existing RAMS, which should remain as the primary source of road network, works, and traffic data. The intention is rather to supplement the RAMS data to account for economic activity. The application of the road maintenance prioritisation model to the Mpumalanga provincial road network showed that both a surface- and functional classification system-based prioritisation schedule are sub-optimal. However, the National Treasury (2018a) detected that some road authorities use one or both of these variables to prioritise economically important roads. The example application of the road maintenance prioritisation model also generated a pareto improvement, with more roads – and importantly roads vital for trade – maintained with the same available budget. Road authorities should therefore follow this prescribed method to generate road link specific CE ratios, which can be introduced as decision variables within the RAMS to prioritise the maintenance of road links that maximise economic growth.

10 CONCLUSION

10.1 SUMMARY AND SIGNIFICANCE OF THE RESEARCH

The first step towards improving the efficiency of road investment in South Africa is ensuring that public and private stakeholders properly understand and appreciate the importance of road investment. Policy frameworks such as the National Development Plan (NDP) already set efficient road investment as a policy imperative, thereby aligning many stakeholders with the research objective to establish the foundation for a national road investment prioritisation model. To supplement the policy importance given to efficient road investment, Chapters 2 and 3 apply a model of output in combination with statistical information and case studies to emphasise the fundamental contribution of road investment to the South African economy, specifically the potential for efficient road investment to help avoid the low-growth middle-income trap and achieve the economic growth targets set by the NDP. It is important to reiterate that the dominance of road transport for both freight and passenger movement is expected to prevail over the medium to long term, but perhaps indefinitely if the National Rail Policy is unable to meet its objectives. These introductory chapters compile, analyse, and contextualise a large body of information to convince stakeholders that improving the efficiency of road investment is among the most important national policy imperatives.

The objective of an efficient road investment policy can readily be juxtaposed with the reality of the South African roads sector. Chapter 4 establishes that in the absence of an efficient national road investment prioritisation model the estimated road maintenance backlog rose from R197.0 billion in 2013 to R416.7 billion in 2017. This estimate is the most detailed and up-to-date evaluation of the road maintenance backlog in South Africa, and signals that the backlog has grown to the point where it presents a structural challenge to road authorities. The implication is that the provincial and municipal road authorities, which are also identified in Chapter 4 as suffering from human capital constraints, are forced to undertake extensive road investment prioritisation exercises.

Prioritising road investments is a complex task that risks violating citizens' right of access to basic services, increasing transport costs, and generating fiscal drag on economic growth. It is thus an obvious concern to find in Chapter 5 that none of the current road maintenance scheduling systems, including bespoke systems such as that developed by Deighton for the Western Cape Department of Public Works and Transport, are appropriate to prioritisation according to the roads sector mandate to (i) satisfy citizens' right of access to constitutionally protected basic services, and (ii) maximally contribute to economic growth. Having scoped the discrepancies between the roads sector mandate and the road maintenance scheduling systems, this thesis pursues a novel solution to this fundamental problem.

An innovative cost-effectiveness analysis-based road classification system is applied in Chapter 6 to classify roads according to the service, or combination of services, they provide based on the road sector mandate. This road classification data can be incorporated as a decision variable in the Road Asset Management Systems to ensure that road maintenance schedules are determined with information about which roads provide access to basic services, which roads support high levels of economic activity, which roads support lower levels of cyclical economic activity, and which roads make a negative economic contribution.

Prior to this thesis, wherever the two objectives in the roads sector mandate did not overlap, road authorities were presented with a difficult choice between prioritising roads satisfying citizens' right of access to constitutionally protected basic services, or roads that maximally contribute to economic growth. Without any definitive guidance about which objective should take priority, road prioritisation decisions have been inconsistent across road authorities and there has been a general bias towards roads that contribute to economic growth. However, Chapter 6 argues there are both constitutional and economic grounds for road authorities to take fully seriously their obligation to provide the required access to basic services before focusing on maximising economic growth. The first lexicographical priority are thus roads that provide citizens with access to basic services.

Road authorities have often only rhetorically affirmed their obligation to satisfy citizens' right of access to constitutionally protected basic services, given concerns about the affordability of this mandate. South African courts have historically tolerated such flexibility by public agencies. An important outcome of this thesis is to show in Chapter 6 that there is no risk of a Hobson's choice between neglecting basic access rights and neglecting the economic growth on which poverty rate reduction depends. Road authorities can maintain the Basic Access Road Network within current budget parameters with significant budget remaining to maintain roads that contribute to economic growth. Moreover, many Basic Access Roads simultaneously fulfil an economic growth function. The cost-effectiveness analysis-based road classification system enables road authorities to effectively complete the first objective of their mandate, in the context of applying their minds to the second one.

This thesis undertakes two optimisation exercises to extend the potential application of the national road investment prioritisation model. Firstly, Chapter 7 recommends a cost-effective surfacing policy for low-volume roads, within which Basic Access Roads are classified. The status quo is that the 454 609 km of gravel roads are maintained as such, unless their traffic volumes are sufficiently high to warrant upgrade to a surfaced standard. The lifecycle-cost analysis builds on previous attempts to motivate that South Africa should follow the growing trend in developing countries and seal all low-volume roads that are worth maintaining at all. The resulting proposed road surfacing policy would give rise to several welfare benefits, including the urgent policy priority to improve the quality and extend the uptake of lower-skilled human capital that has a non-negative shadow value.

Given that South Africa has the 10th longest road network globally, the second optimisation exercise is to identify roads that neither support basic access nor economic growth so that road authorities can rationalise their road networks. This exercise is timely as the *2018 Draft Roads Policy for South Africa* includes a proposal to extend the road network by proclaiming unproclaimed roads, which would exacerbate the sectoral budget constraints and increase the urgency and difficulty of investment prioritisation. Relocating basic service hubs closer to isolated rural communities is explored as a means to remove the basic access function of some single-function Basic Access Roads, thereby creating redundant roads that can be unproclaimed along with other Surplus Roads without compromising either basic access or economic growth. The analysis in Chapter 8 identified 45 757 km of potential single-function Basic Access Roads that may be rationalised via basic service hub relocation. The results of this analysis indicate planning options that merit democratic deliberation and consultative consideration.

Having efficiently satisfied basic access rights, road authorities can confidently procced with a national road investment prioritisation model focused on economic growth. It is important to reiterate that the preceding analyses have to date been neglected, which helps to explain many of the inefficiencies within the South African roads sector and the failings of previous road investment prioritisation models. The concluding task in establishing the foundation for a national road investment prioritisation model is to design and test a model that maximises the contribution of the remaining exogenously determined roads budget to economic growth. Official literature and analysis of the drivers of economic growth in South Africa identify export promotion as the primary variable under policy control to promote national economic growth. The road investment prioritisation model thus applies cost-effectiveness analysis to prioritise road projects that most efficiently support the highest volume of freight, thereby enhancing the productivity and international competitiveness of the largest number of export producers and products. The test application of the road investment prioritisation model to the Mpumalanga provincial road network demonstrates that the model generates a pareto improvement relative to the current road maintenance scheduling systems.

Reflecting on the problem statement in Section 1.1, this analytical sequence significantly contributes to addressing the previously identified core policy failures in the South African roads sector: deterioration in the road network conditions; neglect of citizens' constitutional rights of access to basic services; insufficient prioritisation of roads that best promote the general economy; an excessive rural road network; and the application of inefficient road surfaces that increase both road maintenance and road-user costs and also fail to take advantage of the low shadow price of unskilled labour.

10.2 WIDER APPLICATION OF THE RESEARCH

Many developed and developing countries have based their roads sector mandates around the same two elements as South Africa: to provide access to basic services and to maximise economic growth. This consistency across the roads sector mandates suggests that the methodology used in this thesis might be applicable in other settings. The road classes related to economic growth might remain standard, while the parameters are calibrated to account for varying access standards and applicable sets of basic services. For countries that have undertaken studies on road access to services, this classification system offers a mechanism to incorporate this information in the Road Asset Management Systems. Road authorities interested in rationalising their networks can also apply the classification system to identify unproductive roads and generate redundancies within their networks.

Although less transferable than the cost-effectiveness analysis-based road classification system, the road investment prioritisation model can be applied by countries with similar economic characteristics to South Africa. The road investment prioritisation model is narrowly focused on stimulating national economic growth through export promotion due to the peculiar nature of the South African economy, where: a large proportion of output is sophisticated goods for developed markets, high-tech export sectors are typically the most efficient consumers of financial capital, and government and household consumption expenditure are constrained. This focus limits the direct applicability of the model to developing countries characterised by similarly sophisticated export sectors accompanied by limited domestic middle-class markets, such as Brazil, Malaysia, Philippines, Suriname, Thailand, and Turkey (Fortunato and Razo, 2012).

10.3 FUTURE RESEARCH

The thesis leaves three exercises to future research. The first exercise is to extend the road investment prioritisation model developed in Chapter 9. Once freight origin-destination and input-output data are available, road authorities should follow the example of Souleyrette *et al.* (1998), Brogan *et al.* (2001), and Schroeder *et al.* (2012) and disaggregate freight cargo to better focus the effectiveness measure on export freight. Another potential extension to the application of the prioritisation model is to weight the effectiveness measure according to key variables, such as the value of freight and labour-intensity of the associated sector. These straightforward extensions to the effectiveness measure should better align the road maintenance prioritisation schedule with the NDP objective to support higher value, export freight produced in relatively labour-intensive industries.

The next exercise beyond this thesis is to evaluate the efficiency of the bargaining process that determines resource allocations to the South African roads sector using a public choice model. A rigorous public choice model would help achieve three important outcomes. Firstly, a public choice model would identify the distortionary effects of public officials and interest groups on and within the roads sector budget allocation. This analysis would establish if the bargaining process that determines the resource allocations to the roads sector shifts social welfare towards or away from the social welfare optimum. Secondly, a public choice model would test the hypothesis that it is in the national interest to subsidise South African export sectors through road investment, which as clarified in Section 1.3.1.1 and Chapter 9 is the objective of the road investment prioritisation model. Thirdly, a public choice model would help determine the degree to which the road investment prioritisation model over- or under-subsidises export sectors.

The third exercise remaining beyond this thesis is to optimise the inner-city road networks. Although road planners typically begin by optimising dense urban road networks to promote economic growth, this exercise is preceded in the South African context by the overarching political economy factors of spatial inequality and citizens' right of access to basic services, which both prevail in rural areas. In addition, opportunities to identify economically redundant roads and to use surfacing policy to recruit zero-cost unskilled labour into productive use occur only in rural areas. Having addressed these factors and efficiently supported freight flows across the rural road network, this thesis sets a context in which road planners can focus on efficiently prioritising inner-city road networks.

10.4 NEXT STEPS

Throughout the research a working relationship was maintained with, amongst others, three central stakeholders: The National Treasury; the National Department of Transport (NDOT); and the Western Cape Department of Public Works and Transport. These relationships were formed to ensure the research incorporated the most current data and, given the practical nature of the thesis, was aligned with specific policy and operational concerns. It is therefore pertinent to conclude with recommended steps these, and other, stakeholders can take to incorporate this research within their current and future work agendas.

Firstly, the NDOT should update the road maintenance backlog figure published in the *2018 Draft Roads Policy for South Africa*. Compared to the backlog estimate of R416.6 billion in 2017 in Chapter 4, the 2013 backlog estimate of R197.0 billion significantly underrepresents the required degree of road maintenance prioritisation. This might lead some stakeholders to think the backlog can be solved through additional funding, when really the backlog is so large that long term road maintenance prioritisation is inevitable. The NDOT has been privy to draft versions of this research, with the previous Minister of Transport, Blade Nzimande, presenting elements of this research to parliament (Parliamentary Monitoring Group, 2018).

The next step is for the NDOT to publish the updated road maintenance backlog estimate, which they could shortly update for 2019 using the method developed in Chapter 4.

Secondly, the National Treasury and NDOT can leverage the drive to update the functional classification of roads to implement the cost-effectiveness analysis-based road classification system. As clarified in Chapter 6, these two road classification systems provide different information and should be viewed as complementary rather than supplementary. The NDOT are advised to reference the road classification data to ensure that Surplus Roads are not proclaimed as part of the proposal in the *2018 Draft Roads Policy for South Africa* that all unproclaimed roads must be assigned to local authorities or provinces depending on the functional classification and road significance (National Department of Transport, 2018a).

Thirdly, the NDOT can review the surfacing policy for low-volume roads proposed in Chapter 7 to help develop a national road surfacing policy. The policy proposal is that, under current economic and institutional conditions, gravel roads worth maintaining at all should be sealed at a rate possible within budget limits. This is aligned to, but ahead of the NDOT's efforts to explore alternatives to gravel road surfaces. Until a national road surfacing policy is set, road authorities are encouraged to draw on this research to guide their maintenance operations. For example, the National Treasury (2018a) already used a draft version of this research to help motivate that a portion of the Provincial Roads Maintenance Grant, albeit an arbitrary amount, is available to upgrade gravel roads to a surfaced standard.

In order to realise the potential employment benefits from sealing gravel roads, the National Treasury and Department of Public Works, in combination with other stakeholders such as The Presidency, should support the NDOT pass the proposed national road surfacing policy. The Department of Public Works (2012) generated 46 089 full-time equivalent (FTE) work opportunities in the roads sector in 2010/11 through the Expanded Public Works Program. However, this number of annual FTE work opportunities could increase to around 356 035 were the gravel road network sealed over a 20-year period. These stakeholders must also help with the design of the national road surfacing policy such that it maximises the potential welfare benefits from sealing gravel roads, including: human capital development, reduced short-term rural-urban migration pressures, and substitution of local resources for imports.

Fourthly, the NDOT should initiate consultations with relevant departments of health, basic education, and public works regarding the possibility to remove the basic access function of single-function Basic Access Roads via relocation of basic service hubs. This will allow the NDOT to unproclaim these roads, along with other Surplus Roads, and thereby reduce the maintenance burden on provincial and municipal road authorities. But before this is possible, complex political negotiations would have to occur as this exercise would shift expenditure responsibilities between departments and levels of government. The NDOT should optimise the road network before setting up toll routes on provincial and municipal roads, which is an option raised in the *2018 Draft Roads Policy for South Africa*. Otherwise tolling efficiency might be reduced as road users are presented with more opportunities to divert from toll roads to alternative routes, and the traffic diversions may alter the status of redundant roads.

Lastly, the NDOT should take ownership of the national road investment prioritisation model and facilitate the roll-out of the model to the provincial and municipal road authorities. As custodian of the model, the NDOT will finally have an internally generated road maintenance schedule against which to cross-check the maintenance plans and operations submitted by the various road authorities. The first step in the roll-out process is to apply the model to a provincial road network for at least 12-months, within which time the model can be calibrated to operational demands and the proposed road maintenance schedule compared to the schedule generated by the existing Road Asset Management System. The Western Cape Department of Public Works and Transport is the ideal authority to test the model given that their Road Asset Management System is the most advanced amongst the provincial and municipal road authorities, their staff are suitably competent to interrogate the model and its outputs, and they, in line with the spirit of this thesis, are interested and actively involved in advancing their road maintenance practices.

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