Distance-based road user charges as a road cost recovery method: A South African case study

by
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Declaration

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Signature: Johann André van Rensburg

Date: March 2024

Declaration by the candidate

With regard to Chapter's three through seven, the nature and scope of my contribution were as follows:

Nature of contribution	Extent of contribution (%)
Background research, conceptualised idea for research, research design, data analysis, lead author writing up of article.	75%

The following co-authors have contributed to Chapter's three through seven:

Name	E-mail address	Nature of contribution	Extent of contribution (%)
Prof Stephan Krygsman		Conceptualised idea for research, data analysis, primary research advisor: Ch3, Ch4, Ch5, Ch6, Ch7	25%
Prof Hannelie Nel		Data analysis: Ch4, Ch6	25%

Declaration by co-authors:

The undersigned hereby confirm that:

1. the declaration above accurately reflects the nature and extent of the contributions of the candidate and the co-authors to Chapter's three through seven,
2. no other authors contributed to Chapter's three through seven besides those specified above, and
3. potential conflicts of interest have been revealed to all interested parties and that the necessary arrangements have been made to use the material in Chapter's three through seven of this dissertation.

Signature	Institutional affiliation	Date
Declaration with signature in possession of candidate and supervisor.	Stellenbosch University, South Africa	March, 2024

Abstract

Transport infrastructure, especially relating to the road sector, is an important pillar to facilitate economic development and growth in any country. Roads, however, are subject to large capital outlays for new construction and upgrades, requiring timely maintenance to ensure transport links that are in a satisfactory condition to meet road user demand, improve accessibility and mobility, and reduce vehicle-operating cost. Despite the background of the infrastructure's importance, the road sector is continuing to experience funding deficits, meaning that the current financing and funding methods (also known as road cost recovery methods) are unable to meet budgetary requirements.

This study argues that distance-based road user charges, using Global Positioning System enabled vehicle tracking devices coupled with a short-run marginal social cost fare structure, could potentially augment the research on road cost recovery for an improved road funding framework given the characteristics of the South African road sector. This hypothesis was tested by assessing i) how the South African road-funding framework currently performs in terms of its ability to secure funding for the road sector. Secondly assessing ii) how it will perform in the future, followed by calculating iii) the correct charges to be levied for road use. Lastly, iv) the public acceptability of road cost recovery methods and v) the operational and economic viability of implementing a distance-based road user charge system in South Africa was assessed.

The findings indicate that the South African road funding framework currently collects a large amount of revenue from road users annually, but this is less than what is invested in actual road infrastructure. Compared to select developed countries in terms of how much revenue South Africa collects and spends on road infrastructure as a percentage of Gross Domestic Product, it is definitely not below the norm. The fuel levy, however, although collecting the bulk of the revenue from road users, is becoming increasingly unproductive. It was found that technological and societal trends will have an incremental impact on the future revenue collected from road users in the short to medium term, without necessarily being disruptive. Calculations indicate that the average road user might already be paying more than their fair share of road cost per kilometre of travel and that deriving a short-run marginal social cost fare structure which represents fair and efficient road user charges, as required by the user-pay principle, is by no means an easy endeavour. A public opinion survey indicated that road users

in general do not know the amount of costs they pay for using the road network and that they still favour the fuel levy as the main road cost recovery method to be used in South Africa. Simultaneously, they view distance-based road user charges as an acceptable supplementary option. Through a vehicle tracking study, it was determined that a distance-based road user charge system is operationally feasible and economically viable in South Africa and that if implemented with a short-run marginal social cost fare structure could lead to more equitable pricing while possibly increasing the road funding revenue base.

It is advised that distance-based road user charges be considered to form part of the current road funding framework in South Africa as a supplementary road cost recovery method. Although there are many issues that should still be addressed, it is an avenue worth considering especially from an equity perspective.

Opsomming

Vervoerinfrastruktuur, veral in die padsektor, word gesien as 'n belangrike pilaar om ekonomiese ontwikkeling en groei vir enige land te vergemaklik. Paaie is egter onderhewig aan groot kapitaaluitgawes vir nuwe konstruksie en opgraderings wat tydige instandhouding verg om vervoerverbindings te verseker wat in 'n bevredigende toestand is om aan die vraag van die padgebruiker te voldoen, toeganklikheid en mobiliteit te verbeter, en om voertuigbedryfskoste te verlaag. Afgesien van die agtergrond van die infrastruktuur se belangrikheid ervaar die padsektor steeds befondsingsstekorte, wat beteken dat die huidige finansiering en befondsing metodes (ook bekend as padkosteverhaling) nie aan die begrotingsvereistes kan voldoen nie.

Hierdie proefskrif argumenteer dat afstandgebaseerde padgebruikersheffings, veral deur die gebruik van Globale Posisionering Sisteem geaktiveerde voertuigsporingstoestelle, tesame met 'n korttermyn marginale sosiale kostestruktuur, die navorsing oor padkosteverhaling moontlik kan verbeter vir 'n beter padbefondsingsraamwerk gegewe die kenmerke van die Suid-Afrikaanse padsektor. Hierdie hipotese was getoets deur i) te evalueer hoe die Suid-Afrikaanse padbefondsingsraamwerk tans presteer met betrekking tot die vermoë om befondsing vir die padsektor te bekom, ii) hoe dit in die toekoms sal presteer, iii) die korrekte heffings wat vir padgebruik gehef moet word, iv) die openbare aanvaarbaarheid van metodes vir die verhaling van padkoste en v) die bedryfs- en ekonomiese lewensvatbaarheid van 'n afstandgebaseerde padgebruikersheffingskema implementering in Suid-Afrika.

Die bevindinge dui daarop dat die Suid-Afrikaanse padbefondsingsraamwerk tans jaarliks 'n groot hoeveelheid inkomste van padgebruikers verhaal, maar dit is minder as wat in werklike padinfrastruktuur belê word. In vergelyking met geselekteerde ontwikkelde lande in terme van hoeveel inkomste Suid-Afrika as 'n persentasie van die Bruto Binnelande Produk op padinfrastruktuur verhaal en spandeer, is dit beslis nie onder die norm nie. Die brandstofheffing word egter al hoe meer onproduktief, alhoewel dit die grootste deel van die inkomste van padgebruikers verhaal. Daar is bevind dat tegnologiese en samelewingstendense 'n toenemende impak sal hê op die toekomstige inkomste wat op die kort- tot mediumtermyn van padgebruikers verhaal word en nie noodwendig ontwrigtend sal wees nie. Berekeninge dui daarop dat die gemiddelde padgebruiker moontlik reeds meer as sy / haar billike deel van die padkoste per kilometer betaal en dat die verkryging van 'n korttermyn marginale sosiale kostestruktuur, van fooie, wat billike en doeltreffende padverbruikerskoste verteenwoordig,

soos vereis deur die gebruikersbetaalbeginsel, geensins ’n maklike poging is nie. ‘N openbare meningsopname het aangedui dat padgebruikers in die algemeen nie weet wat die koste is wat hulle betaal vir die gebruik van die padnetwerk nie en dat hulle steeds die brandstofheffing verkies as die hoofmetode vir die verhaling van padkoste in Suid-Afrika, maar dat die afstandgebaseerde padgebruikersheffings vir padgebruikers ’n aanvaarbare aanvullende opsie is. Deur ‘n voertuignasporingstudie is daar bevind dat ’n afstandgebaseerde padgebruikersheffing sisteem in Suid-Afrika operasioneel haalbaar en ekonomies uitvoerbaar is en dat as dit geïmplementeer word met ’n korttermyn marginale sosiale kostestruktuur dit tot billiker pryse kan lei, terwyl die padbefondsingsinkomstebasis moontlik vergroot kan word.

Dit word aanbeveel dat afstandgebaseerde padgebruikersheffings oorweeg word as deel van die huidige padbefondsingsraamwerk in Suid-Afrika as ’n aanvullende metode vir die verhaling van padkoste. Hoewel daar baie kwessies is wat nog aangespreek moet word, is dit ’n benadering wat die moeite werd is om te oorweeg, veral vanuit n bilikheids perspektief.

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Over the past couple of years, I have experienced a mixture of emotions in my life. At first, I was filled with excitement, starting a new career in academia and pursuing a PhD degree on a topic that is very interesting and relevant in the current setting, yet controversial. This soon turned into fear when I realised how wrongfully overconfident I was, having thought research on this scale would be a walk in the park while being undertaken in an academic environment. I did not take into account the magnitude of duties expected to be performed by a university lecturer, not anticipating the massive change and responsibility to come in my family life with the birth of my two children, and being blatantly ignorant in thinking I know everything. Without the help and support of the people around me, the completion of this dissertation would not have been possible, and for this I will be forever grateful.

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through the good times and the bad, and allowing me to pursue my dream of obtaining a PhD degree.

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Abbreviations

AA	-	Automobile Association of South Africa
AARP	-	American Association of Retired Persons
AARTO	-	Administrative Adjudication of Road Traffic Offences
AfDB	-	African Development Bank
BER	-	Bureau for Economic Research
BRICS	-	Brazil, Russia, India, China and South Africa
CGE	-	Computable General Equilibrium
CPI	-	Consumer Price Index
DBRUC	-	Distance-Based Road User Charges
DSRC	-	Dedicated Short-Range Communications
ETC	-	Electronic Toll Collection
EU	-	European Union
EV	-	Electric Vehicle
GDP	-	Gross Domestic Product
GFIP	-	Gauteng Freeway Improvement Project
GNP	-	Gross National Product
GNSS	-	Global Navigation Satellite System
GPS	-	Global Positioning System
GSM	-	Global System for Mobile
HGV	-	Heavy Goods Vehicles
ITS	-	Intelligent Transport Systems
Km	-	Kilometres
MSC	-	Marginal Social Cost
NATMAP	-	National Transport Master Plan
NDP	-	National Development Plan
NHTS	-	National Household Travel Survey
NLTSF	-	National Land Transport Strategic Framework
OBD-ii	-	On-Board Diagnostic System Unit
ODOT	-	Oregon Department of Transport
OECD	-	Organisation for Economic Co-operation and Development
PAYD	-	Pay-As-You-Drive
PPP	-	Purchasing Power Parity

PRSN-MCP	-	Perceived Risk-Based Stochastic Network Marginal Cost Pricing
RAF	-	Road Accident Fund
RUCPP	-	Road User Charge Pilot Program
RUFTF	-	Road User Fee Task Force
SADB	-	Southern African Development Bank
SAM	-	Social Accounting Matrix
SANRAL	-	South African National Road Agency Limited
SARS	-	South African Revenue Service
SOE	-	State-Owned Entities
SPSS	-	Statistical Package for Social Sciences
UK	-	United Kingdom
USA	-	United States of America
VAT	-	Value Added Tax
VMT	-	Vehicle Miles Travelled

"If a variety of fuels become available with differing efficiencies and consumption effects, fuel taxation may become very complex which might make some alternative system, such as charging directly according to distance travelled, a more attractive proposition than at present."

(Freeman, 1982)

Chapter 1. The recovery of road cost

1.1 Introduction

The past few decades have seen a growing and ongoing academic and policy debate on how and to what extent cost incurred on the road network (i.e. maintenance cost) and society (i.e. congestion, accident and environmental cost) by road users should be recovered. This deliberation is mainly attributed to an ever-increasing funding gap between the revenue collected from road users and the road expenditure requirements for the construction, maintenance and upgrading of roads. Arguably, the conventional road cost recovery methods, such as the fuel levy, are failing in adequately securing funding for roads and that new innovative road cost recovery methods are needed. More recently, Global Positioning System (GPS) technology has been incorporated into the theorised system of charging road users based on the distance that they travel, by accurately capturing their vehicle's distance of travel, the time and place where the travel occurred and then charging an appropriate fee for the use of the particular road infrastructure traversed. This charging system address numerous shortcomings of conventional road cost recovery methods, whereby it is a more direct method of charging road users while incorporating the user-pay principle and a more equitable form of charging whereby the fuel efficiency of vehicles is ignored. This road cost recovery method, commonly referred to as Distance-based road user charges (DBRUC), has not yet been investigated nor tested in the South African context. It is unknown whether this road cost recovery method is indeed required and appropriate to supplement road cost recovery methods in the South African road-funding framework and whether it is possible to implement such a system in South Africa. The South African road-funding framework refers to numerous government acts, bills and policy documents that guides the collection and expenditure of funds in respect to the road sector.

This study aims to expand on the current research of road cost recovery by evaluating the need, appropriateness and practicality of using DBRUC as a road cost recovery method in the South African road-funding framework. This will be done by assessing i) to what extent the South African road-funding framework is able to secure funding for roads, ii) to what extent the current South African road cost recovery methods will be able to secure funding for roads in the future given the emergence of disruptive transport technologies and societal trends, iii) to what extent the South African road-funding framework reflect fair and efficient road user charges, iv) to what extent South African road users view current and proposed road cost recovery methods within the country's road-funding framework, and v) to what extent DBRUC are operationally feasible and economically viable in South Africa.

This chapter continues by providing background information to the research problem and discusses the research gaps that this study aims to address. The theoretical and conceptual framework adopted throughout the rest of the study follows this. The chapter then discusses the study's research aim, research questions and research objectives, while the chapter concludes by providing an overall outline of the study.

1.2 Background and research gaps

The earliest inhabitants of earth lived together in small communities. These communities developed transport routes by being nomadic hunters following animal trails. As these communities developed, it settled in areas with an abundance of resources leaving communities scattered within a country. Making these areas productive required transport infrastructure in order to provide accessibility and mobility for the manufacturing industry, business and retail sector and residential areas, while enabling faster travel times and travel cost savings. This was facilitated mainly through road infrastructure.

Roads are undeniably important to any country as, among others; it can lead to an improved standard of living for the public, provide a social service and support economic growth and development. As its main purpose, roads allow individuals to travel to work reliably and safely, to acquire products without excessive transportation expenses or delays and to use services that depend on others to reach their destination (Terril, Emslie & Coates, 2016). Good roads lower cost of transport due to lower vehicle operating costs and travel time (the direct effects). These leave firms with more time and money to produce goods and provide services. Households are similarly left with more time and money to spend on goods and services. All of this leads to an increase in output and productivity. The indirect effects or the wider economic effects include, among others, higher employment, spatial agglomeration benefits (clustering of industry), improved accessibility, innovation and commercialisation of new knowledge in connected areas, and economic growth (Lakshmanan, 2011). In fact, it is hard to think of any economic, social or cultural activity where roads are not required in some form or other. Poor quality roads, of course, have the opposite effects (Department of Logistics, 2017).

Thus, roads are one of the most valued infrastructure items in any country. The quality and size of the road network are however dependent on sufficient maintenance, timely upgrade and appropriate new construction of the infrastructure to ensure a well-maintained, effective and safe road network, which in turn are dependent on sufficient and stable modes of funding and adequate financing. Public infrastructure funding represents who eventually pays for building and maintaining the infrastructure throughout its lifetime, whereas financing relates to the capital required to pay up front for the investment expenses. The costs of poor road management and insufficient road funding and financing are, after all, borne mainly by road users through increased vehicle operating costs, longer travel times and possibly an increase in traffic accidents.

Despite the general belief in the importance of roads, funding is often controversial, faces many conflicting viewpoints and is notoriously complex. This situation is exacerbated in developing countries, such as South Africa, which faces numerous developmental requirements, limited revenue opportunities and a relatively small road user base. Given the nature of road infrastructure, i.e. indivisible, large and a public good, financing for roads are nearly always under pressure. The government cannot always ensure that sufficient funds are spent on roads because of other urgent development requirements of the country, or that the spending on roads is done in an economically efficient manner. To compound the problem, road users seldom, if ever, know the full cost of their road use and mostly under-estimate the cost of their use of road infrastructure, which is a scarce resource.

South Africa has seen its fair share of public debate on how the government should fund transport infrastructure and, increasingly, transport operations such as public transport. Roads, in particular, have received a lot of attention in the popular press, with statements regarding alternative funding options to increase funding demands made by three main interest groups: the government, state-owned entities (SOE) and the public. Their viewpoints are often conflicting with some groups arguing for and other groups arguing against the fuel levy, the ring-fencing of the fuel levy and toll roads. The groups also differ in their views on whether motorists are unfairly taxed and that the road sector is subsidising other economic sectors. A general theme in government policy papers seems to indicate their preference for adopting the user-pay principle to fund roads (Department of Transport, 2013, 2017, 2018). There is generally very little discussion on what the user-pay principle entails. What complicates the situation in South Africa is that the road industry, broadly defined as road users, infrastructure service providers, transport operators, government and SOEs, seems saturated with distrust, suspicion and with untruths about road funding. There is no consensus on which road cost recovery methods to use, there is limited knowledge about what is collected from road users and non-users, there is confusion about how much money is being invested in the road network, and there is a limited knowledge base to substantiate current road user charges. Within this environment, it is very difficult to implement any new road user charges or corrective measures or to promote a sustainable road infrastructure funding policy.

Currently, the main revenue source from road users in South Africa is the fuel levy. However, it is argued that the strong link between road use and the fuel levy, which was inherent at the inception of the levy, has become decoupled over time. Road users therefore do not pay an appropriate fee for their actual use of the road (Jaffe, 2015). The fuel levy can also be seen as a regressive tax as opposed to a progressive tax whereby the lower socio-economic classes are hit the hardest due to everyone paying the same amount. Normally, these classes tend to own and drive vehicles that are less fuel-efficient. Relative to fuel efficiency, road construction costs, driven by inflation, scarcity of natural resources and labour cost, have increased (Jaffe, 2013a). Similar to the situation in the United States of America (USA), South Africa needs to spend more on roads than it can generate from road charges (Jaffe, 2013b). As a result the road maintenance backlog in South Africa is estimated at R197 billion (Kannemeyer, 2014). The shortfall is usually funded from municipal rate taxes paid by local residents and transport grants (Freeman, 1982). Moreover, while the fuel levy is charged nationally, it is used to fund roads in particular areas, which results in a spatial discrepancy between those who pay for road maintenance (everyone) and those who benefit (the region) from it. At this moment, electrical and hybrid vehicles do not contribute to the fuel levy, despite the fact that they incur costs on the road network (i.e. maintenance, congestion etc.) due to their usage of roads. Advances in vehicle technology will lead to more fuel-efficient vehicles and as a result less fuel will be used to travel the same distance. Increasing the levy on fuel on the other hand will result in a corresponding rise in transport rates and expenses that will affect inflation. A rise of 10% in fuel prices was projected to result in an rise of 0.7% in consumer inflation (net food prices) after seven months (Kantor & Barr, 1986). Lastly, through the fuel levy, road users do not really consider their road use cost when driving and the levy does not induce individuals to modify their travel behaviour.

A brief review of international literature found that the problems associated with the fuel levy are not unique to South Africa. In numerous countries, including the USA, European countries and New Zealand, this phenomenon is also encountered. However, these nations are actively looking for feasible solutions to the decreasing fuel revenue source (Abou-Zeid, Ben-Akiva, Tierney, Buckeye & Buxbaum, 2008; Sorensen & Taylor, 2005; Whitty & Imholt, 2007). The most innovative cost recovery method currently being researched is DBRUC that charge vehicles directly for each kilometre or distance of travel. This system, in general terms, entails on-board GPS-enabled devices with Global System for Mobile (GSM) communication technology to be fitted to the vehicle where information on distance travelled, time of travel and type of road travelled upon is collected. Information is then analysed through a back-end system to produce a road usage invoice at a fixed or variable price per kilometre travelled per vehicle class, depicting the additional road use cost to be paid by the vehicle owner after a rebate of the fuel levy that has already been paid (Coyle, Robinson, Zhao, Munnich & Lari, 2011). Numerous DBRUC studies and pilot projects are being undertaken around the world, each with different goals and designs (Mileage-Based User Fee Alliance, 2015). In the USA, 26 states are engaged in pilot projects, legislative amendments and the formation of local and global consortia involving DBRUC systems (Slone, 2015). In Europe, this road cost recovery method has been implemented in various forms for heavy good vehicles in countries such as Switzerland, Austria, Germany, Hungary, Slovakia, the Czech Republic and Poland, while France, Belgium and Russia are all developing freight truck-based systems (Mahendra, Grant, Higgins & Bhatt, 2011). New Zealand has a comparable system for all heavy good and diesel-powered vehicles (Road User Charges Review Group, 2009). At the turn of the century, innovations in technology skyrocketed and became cheap and easily accessible which made DBRUC, as a road cost recovery method, feasible.

Distance-based road user charges is considered the best solution to the present issues presented by the fuel levy (Coyle *et al.*, 2011). Supplementing or replacing the fuel levy with a feasible option that directly charges road use by tracking the real distance of vehicle travel will guarantee an effective method for recovering road costs that is not affected by technological and societal developments and does not depend on fuel sales. This method can also be a progressive tax, generating more income to keep up with the expenses of road construction and taxing road users for actual road use. It is a policy-sensitive alternative according to which changing the levy impacts on road users' travel behaviour. It is relatively easy, at least in theory, to enforce and educate road users about the road cost they incur through an itemised monthly bill (Jaffe, 2015). Distance-based road user charges have excellent flexibility in planning and implementation and this charge could differ depending to vehicle type, fuel efficiency, time of day, or location (Zhang, McMullen, Valluri & Nakahara, 2009). This road cost recovery method also conforms to the user-pay principle and the economic efficiency principle (Rouwendal & Verhoef, 2006). The road user who is also the beneficiary will bear the full cost of using that road as drivers with fuel-efficient and alternative fuel vehicles will not be able to avoid payment because, unlike the fuel levy, the fee is not based on fuel consumed but on actual travel. Furthermore, the user can be charged at marginal cost by applying variable rates per kilometre that will internalise externalities and ensure an efficient distribution of scarce resources (road infrastructure) that would lead to economic efficiency.

South Africa has in recent years reiterated that transport is a pillar for economic development and growth and must receive adequate funding in its National Development Plan (NDP). In the country's new proposed roads policy it acknowledges the current funding deficit between the income collected from road users and the budgetary requirements of road infrastructure indicating the requirement to investigate weight over distance charging and other new innovative road cost recovery methods that incorporate the user-pay principle.

Although securing funding for the road sector in South Africa is more challenging than ever while competing with other economic responsibilities, the current scientific debate on road cost recovery includes several areas that require further research before a DBRUC system can be implemented in South Africa. First, local allegations that the conventional fuel levy is not sufficient any more to fund road construction, maintenance and upgrades have led to a fiery debate about the future of using this model as an economically efficient road cost recovery method. This was made apparent with mass protest action, court cases and payment refusal with implementation of the controversial Gauteng Freeway Improvement Project (GFIP), as from 2015, which intended to recoup more road user cost from motorists to provide upgraded road infrastructure and alleviate congestion. What is unknown within the South African context is the extent to which the country's road-funding framework and its road cost recovery methods are able to secure funding for roads as the proses is not administered by a central authority, but rather adjudicated to various governmental spheres as mandated in the South African Constitution. Second, the road cost recovery method's revenue might be impacted by future technological improvements and societal changes that have not been taken into account in recent research on road cost recovery. Third, local policy documentation does not seem to have a clear mandate about how to recover cost nor how to set fair and efficient prices, simply referring to the user-pay principle that should be adopted. A road user charge policy seems lacking locally, although it has become standard internationally. Fourth, it is furthermore unknown how road users and non-road users perceive road pricing or will perceive a new road cost recovery method such as DBRUC and whether it will be publicly accepted in the current political environment. Fifth, a DBRUC system has not previously been tested in South Africa and it is unknown whether this method is operationally feasible and economically viable, especially in South Africa's current economic climate with its available technological infrastructure. The research presented in this study aims to address these gaps.

1.3 Theoretical and conceptual framework

A sound theoretical base exists that justifies why road users should pay for their use of road infrastructure and how road cost incurred by the road users can practically be recovered from them. It is a widely accepted economic principle that users must carry the full and real cost of their consumption or utilisation to ensure that scarce resources are allocated fairly to users. Amongst other things, this will ensure that the different modes of transport compete with each other on an equal footing and that the road users and others that benefit from the road network carry their fair share of the costs without having to be subsidised from other sources.

Walters (1968) states that there are two methods available to allocate road user cost, namely the fixed costs method and the development cost method. The fixed costs (or sunk costs) related to the building, expansion or improvement of existing roads are spread over a particular period and divided among subsequent generations of consumers according to the fixed costs method, also known as the historic costs method. There are two steps: First, an estimate is made of the value of the capital invested in the physical facilities and then a representative discount rate is selected to spread the value of the capital evenly over the lifespan of the road network. In turn, the development cost method (current cost method) ignores the fixed costs of existing roads and concentrates on the recovery of current or future costs related to the building, expansion or improvement of the road system in one of two ways, namely (i) the development costs or long term marginal costs method and (ii) the incremental method.

According to the long term marginal costs method, the costs related to the provision of a new road or future road space are determined by the value of future services that will be made possible by the road. Present users are thus charged in advance for future costs. The only difference between the incremental method and the long-term marginal costs method is that it also considers marginal costs, in other words it amounts to "pay with utilisation".

The foundation of cost responsibility should in general be fair and at the same time easy for both those who benefit and for the administrators of the recovery to understand. Cost responsibility can be allocated according to three principles: (1) the benefit principle, (2) the ability-to-pay principle and the social economic cost responsibility principle. According to the benefit principle, the costs of road provision must be recovered from those who benefit according to the value of each one's benefit. The ability-to-pay principle differs from the benefit principle in that it is not directly related to benefits received. Its viewpoint is that the community as a whole is responsible for the required infrastructure, and the costs must be recovered according to every consumer's ability to pay. Lastly the social economic cost responsibility principle assumes that consumers (for economic efficiency) must carry the full costs of their usage, but admits at the same time that other deserving causes can also be financed out of taxes.

In addition, Freeman (1981) discusses eight methods to allocate road cost responsibility in a fair and just way. This includes (i) the Standard cost method which application rests on the estimated cost of building and maintaining a main traffic artery, (ii) the Gross ton kilometre method that assumes that the road infrastructure costs are related to the gross mass and size of the vehicles and the distance travelled by them, and that the benefits are in ratio with the number of ton kilometres (km) travelled, (iii) the Operating costs method that assumes a direct relationship between the value involved in the use of a road and the operating costs of the different classes of users, (iv) the Space-time method which assumes that the use of a vehicle and the road system required for such use can be measured according to the road space that the given vehicle requires and the total time during which the vehicle occupies that space, and (v) the Differential benefit method that represents the most purposeful attempt to apply the benefit principle. It is assumed that the consumers' tax on vehicles of different sizes and masses must be in relation to the benefit that road use holds for them. Additionally, (vi) the Inverse elasticity method which allocates road costs to users according to their willingness to pay as indicated by observed reactions of different groups of consumers to increases in road users' costs, (vii) the Incremental cost method that assumes that the different elements of road construction and maintenance are influenced by the size and mass of the vehicles on the road, and that the costs of these elements can be subdivided into increments relating to this use and lastly (viii) the Cost function method which is derived from the incremental cost approach and differentiates between three types of road costs. These include costs influenced by or connected to the vehicle's characteristics or the axle's characteristics such as mass or size, costs that vary according to the extent of road use, but not vehicle characteristics, and costs that are independent of vehicle characteristics and road use.

All three spheres of government as well as SOEs responsible for road construction, upgrade and maintenance can access various sources of financing. These include (i) an equitable share of the revenue raised nationally and distributed from National Treasury to the various Government departments, to provide basic services and perform the functions allocated to it in terms of section 214 and 227 of the Constitution. Furthermore (ii) general sources of revenue which include direct allocations from national government to provincial and local government, subsidies and loans. National Government, in turn, can use (iii) a variety of economic elements like personal revenue tax, company tax, and value added tax (VAT). Local, and in some cases, provincial governments generate own revenue by way of (iv) rates and services charges. Surpluses generated from these sources, after providing the required services, may be used to finance assets. Other revenue sources related to transport include heavy vehicle permits, license and registration, parking fees and development impact levies. Additionally, financing can be sourced from (v) Development Bank loans, bonds issued by the Infrastructure Finance Corporation, commercial bank loans and Municipal bonds. Revenue can also be acquired from donations and loans at favourable interest rates offered to the road authorities by organisations like the African Development Bank (AfDB), the Southern African Development Bank (SADB) and the World Bank. Local authorities can also use (vi) loan capital. Governments can also use (vii) non-traditional and sometimes innovative approaches to fund transport infrastructure and maintenance. These approaches includes Grant anticipation revenue such as bonds, notes, certificates, mortgages, or leases and Public-private partnerships.

Numerous practical road cost recovery methods exists which authorities may use to secure funding for its road network. These include (i) Road user levies such as toll systems, supplementary licensing and electronic toll systems. Additionally, (ii) Vehicle levies such as taxation on fuel, taxation on tyres, levies on vehicle parts, mass-distance taxation, taxation on new vehicles, license fees, road transport permits and axle or wheel tax. The option also exist to apply (iii) Parking and loading levies and (iv) Trip generation levies such as contributions by established businesses and land development contributions. Moreover, (v) Commercialisation where income is generated through service delivery and from assets, and (vi) Local government tax such as property and land taxation, service levies and other general revenue sources.

In line with the above review of literature, the conceptual framework presented in Figure 1.1 was developed.

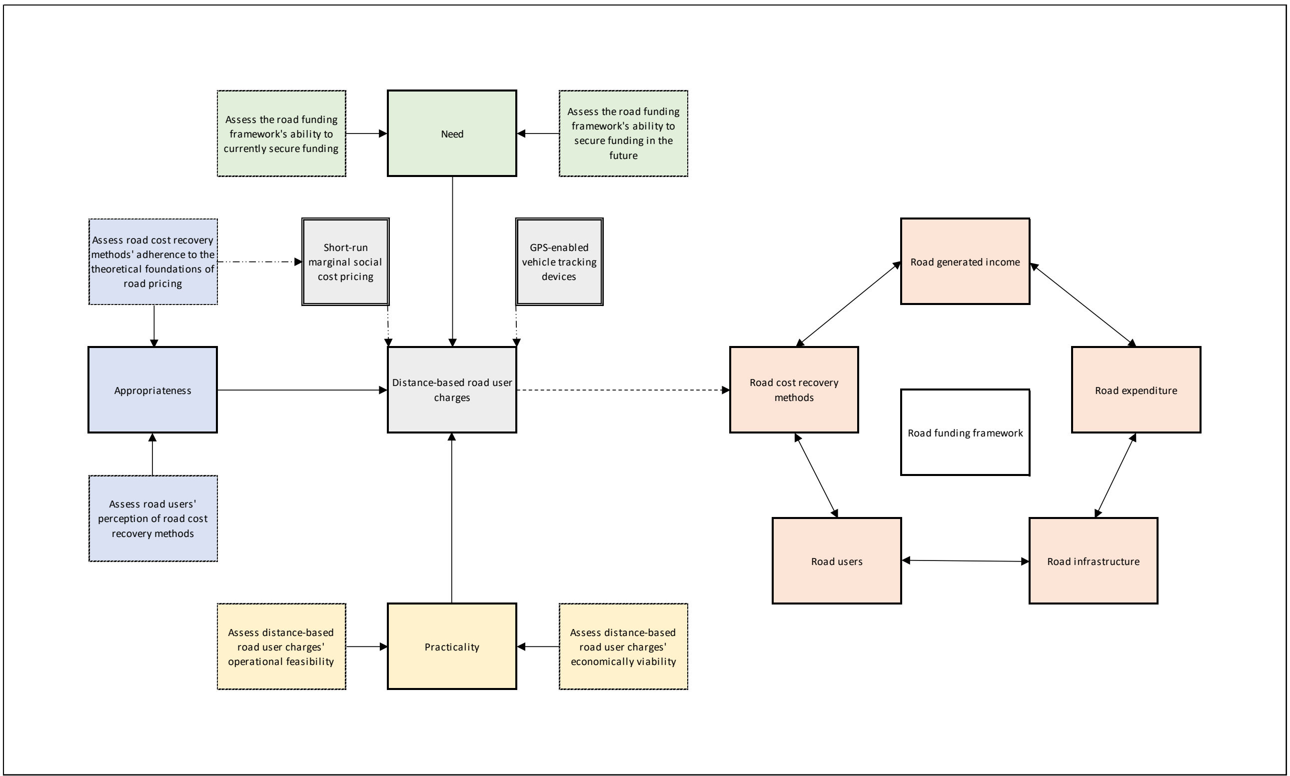

Figure 1.1 | Conceptual framework
(Source: Own)

The South African road-funding framework is driven by numerous government policies to create a transportation-funding environment that fosters sustainable development and growth. This funding framework is built on the premise that numerous road cost recovery methods are employed to generate revenue from road users to fulfil the country's road expenditure requirements. The magnitude of the funding required stems from the current road infrastructure construction, maintenance and upgrade requirements to fulfil road users' needs. These requirements are based on the premise that the provision of road infrastructure will lead to improved accessibility, mobility, shorter travel time and reduced road user costs for motorists using the infrastructure. The road cost recovery methods essentially allocates road costs to road users and then collects the road-generated revenue from them that can be used as road expenditure on infrastructure. In turn, the amount of road users and the quality of the road infrastructure they need will determine the required road expenditure to be financed by the road-generated revenue recovered by the cost recovery methods.

Conversely, it is argued that the road cost recovery methods currently employed in the South African road-funding framework are not able to meet the budgetary requirements for road expenditure, nor is it able to charge road users accurately for all the costs that they may incur. At the time of road usage, the road users create certain private and external costs. Private costs such as the cost of fuel, insurance and vehicle bond payments are internalised by the motorist, but the externalities created by road use are not. This is because these external costs, which include maintenance, congestion, accident, and environmental costs (also known as social cost) at their marginal level are rarely seen or quantifiable by the road users or society. For these reasons, a supplementary road cost recovery method may be required that can recover these costs from road users.

This study will focus on the South African road-funding framework with specific reference to its road cost recovery methods. It is within this environment that the need, appropriateness and practicality of DBRUC will be investigated as a supplementary road cost recovery method. The DBRUC design in this context will incorporate GPS-enabled vehicle tracking devices and a short-run marginal social cost (MSC) fare structure.

First, the need for DBRUC must be established by assessing the revenue-generating capability of the current road-funding framework. This is done by considering the road cost recovery methods and if whether they can generate sufficient revenue to meet the country's budgetary requirements for road expenditure at present and in the future with the advent of technological advances and changing societal trends. Second, the appropriateness of the road cost recovery methods for increased reliance on road user charges that emphasise both economic efficiency and fairness must be assessed together with how road users view, perceive and accept these methods. Third, the practicality of implementing DBRUC through their design to be operationally feasible and economically viable must be assessed through vehicle tracking experiments. These experiments must assess whether the principles of economic efficiency and fairness through short-run MSC can be employed effectively to set prices at an appropriate level to generate adequate revenue for road expenditure.

1.4 Research aim, questions and objectives

With the ever-increasing innovations in technology that directly affects the fuel efficiency of modern-day vehicles and reduces the productivity of conventional road cost recovery methods, the requirement to effectively recover road user costs is more important than ever. This is reflected in a wide range of studies on the sustainability of the fuel levy and DBRUC systems (Coyle *et al.*, 2011; Forkenbrock, 2005; Goodin, Baker & Taylor, 2009; Goodin, Wood & Baker, 2011; Goodwin, Baker & Pourteau, 2009; Hatcher, Bunch, Hardy, McGurrin & Hardesty, 2009; Whitty & Imholt, 2007). However, no consensus has been reached on the question of whether a broad implementation of a DBRUC system is required, appropriate and practical to secure adequate revenue from road users in an equitable manner, especially in South Africa. This study argues that GPS-enabled vehicle tracking devices coupled with the theoretical system of the user-pay principle through a short-run Marginal Social Cost (MSC) fare structure could potentially augment the research on DBRUC programmes to recover road user cost in a fair and efficient manner. Vehicle tracking devices can not only source telemetry data but coupled with a back-end system can provide individuals with real-time information, feedback, suggestions and invoices on their daily travel behaviour based on the type of road travelled upon, the distance travelled, time of travel and the resulting cost that should to be paid for the externalities not internalised by the road user. However, between collecting telemetry data and providing feedback to individual road users, significant research is required in understanding the capability of the South African road-funding framework at current and for the future, deriving efficient and fair road user charges, assessing public opinion on the acceptability and favourability of road cost recovery methods and testing the operational feasibility and the economic viability of a DBRUC system in South Africa. The aim of this study is therefore:

To evaluate the need, appropriateness and practicality of DBRUC using GPS-enabled vehicle tracking devices and a short-run MSC fare structure as a road cost recovery method in the South African road-funding framework.

This aim will be addressed by answering the following five research questions:

Research question 1: To what extent is the South African road-funding framework able to secure funding for roads?

It is widely speculated, denied and even acknowledged to some extent that South Africa's road-funding framework in its current state is unable to recover sufficient funding for its road infrastructure expenditure programmes. This has created an industry saturated with distrust, suspicion and untruths about road funding. Current policy frameworks, financial statements and reports of road-based government entities do not collectively show the available funding and limits on funding, the distribution of the funding based on the socio-economic and transport development objectives, and the beneficiaries of the funding. It is entirely unknown how South Africa compares to other countries in terms of the funding collected and then the amount invested in the road infrastructure. Moreover, the general fuel levy has been in the crosshairs for some time, even more so with the advent of electronic toll collection systems. Its capability, or rather productivity, to secure funding for the country at present and in the future is still relatively unknown. With research question 1, the intent is to i) quantify the South African road-funding framework through a budget analysis, ii) compare the quantified South African road-funding framework internationally through a comparative analysis, and iii) measure the economic efficiency of the South African fuel levy through a productivity analysis.

Research question 2: To what extent will the current South African road cost recovery methods be able to secure funding for roads in the future given the emergence of disruptive transport technologies and societal trends?

Current research in South Africa only focusses on the effect of increasing the fuel levy at a provincial level and ignores all other road cost recovery methods currently employed. The fuel levy's revenue potential for the future is often miscalculated and the research is oblivious to any effect that emerging transport technologies and resulting societal trends already have and may have on future government revenue from the road sector. With research question 2, the intent is to i) forecast the revenue of South Africa's road cost recovery methods through a time series forecast (ARIMA), and ii) estimate the potential revenue impact of disruptive transport technologies and societal trends on South Africa's road cost recovery methods through a scenario analysis.

Research question 3: To what extent do the South African road-funding framework reflect fair and efficient road user charges?

At present, there is no theoretical basis that can justify the monetary values assigned to the road cost recovery method's charges or fees that are levied to recover costs from road users in South Africa. These values seems to be adjusted annually based on governmental budgetary and developmental requirements. A study of the theoretical foundations of road pricing, especially the system of the advocated user-pay principle that is to be adopted in the country, is required to present an outline of how cost for land transport, road infrastructure and operations should actually be calculated, allocated and recovered in South Africa. The fees charged by the different road cost recovery methods do not conform to basic road pricing theory that suggests equitable, fair and economically efficient prices known as short-run MSC and as such usually leads to unsatisfactory (also known as second best) pricing. With research question 3, the intent is to i) calculate the impact of the South African road-funding framework on road users through an impact assessment, and ii) derive a short-run MSC-based road user charge through the use of the social economic cost responsibility principle and purchasing power parity (PPP) theory.

Research question 4: To what extent does South African road users view current and proposed road cost recovery methods within the country's road-funding framework?

The public's perspective and acceptance of road cost recovery methods are important, as the public will be the users of the system. They represent one of the main road user groups as well as the majority of the population. Hence, they have the power to block the system as seen with the e-toll fiasco in Gauteng. No extensive research on the opinion of road users regarding road pricing in South Africa has been undertaken and although developed countries' research in this regard is at a more advanced state than that of South Africa, their questions to road users are too limited to truly assess public opinion on an advanced level. With research question 4, the intent is to i) collect public opinion regarding the fuel levy and DBRUC through an online survey.

Research question 5: To what extent are DBRUC operationally feasible and economically viable in South Africa?

It is currently unknown whether a DBRUC system could be operationally implemented in South Africa given the technology and expertise required to implement such a system. Moreover, the literature demonstrates that current DBRUC initiatives use a flat fee structure that is merely a conversion of the fuel levy on a per kilometre basis and that short-run MSC pricing, which indicates fair and efficient prices, is only modelled in a simulated environment, not giving an indication of the economic viability of such a system. With research question 5, the intent is to i) generate a DBRUC invoice in South Africa through a vehicle tracking study, and ii) calculate the revenue potential of a DBRUC system in South Africa through a cost allocation analysis.

1.5 Dissertation outline

To meet the stated aim of this study and answer the research questions by addressing the related objectives, as stated in the previous section, this study adopts an article-based approach and presents the findings from seven articles. Each article's findings are presented as chapters or are combined into chapters. The findings are either published in a national peer-reviewed journal (Chapter 3), published in national and international peer-reviewed conference proceedings (Chapter 3, 4, 5 and 7) or prepared for submission to an international peer-reviewed journal (Chapter 6).

Chapter 2 presents a comprehensive literature review to provide a clear understanding of DBRUC and where it fit into the road-funding environment. The existing knowledge and research on this system and related areas or challenges that require further research are discussed. This chapter starts by placing the DBRUC system in context by reviewing how road cost is recovered by various practical methods. Problems associated with the main road cost recovery method used around the world, the fuel levy, and insight into possible solutions suggested by researchers are considered by delving deeper into the efficiency of this method. As the link between road cost recovery methods and road use are becoming less efficient the focus shifts to road pricing, and eventually leads to the argument for DBRUC which is viewed as a more direct method of charging individual road users to recover cost imposed on the road network. Following on this is a discussion on the DBRUC system through exploring implementation and policy challenges identified by various academics, after which a quantitative account is given on the possible effects of DBRUC through system modelling. The literature review then presents numerous DBRUC experiments by means of vehicle tracking and public opinion studies and provides information of where and how DBRUC systems or derivatives of this method have been wholly or partially implemented. Lastly, the chapter concludes with suggestions of directions for future research.

Chapter 3 addresses research question 1, which evaluates the need for DBRUC by assessing to what extent the South African road-funding framework, is able to secure funding for roads. The chapter starts by introducing the topic of understanding the South African road-funding framework while explaining its relevance to the study, stating the aim and objectives and outlining the main points of the research. Thereafter a review of literature pertaining to the history and evolution of road funding in South Africa and how the current policy framework is changing is presented. It continues by providing a description of the research methodology employed to address the chapter's aim which includes a budget analysis, comparative analysis and productivity analysis, outlining the objective of each method, describing the method design and limitation. This is followed by presenting the research results firstly from quantifying the South African road-funding framework through a budget analysis which provides an overview of the South African road network and then gives an account of the collection, allocation, expenditure and the distribution process of funds in the South African road-funding framework. This is done by means of reviewing government and road-related SOEs' financial documents. Secondly from comparing the quantified South African road-funding framework internationally through a comparative analysis with reference to its road expenditure to revenue ratio, its road expenditure to gross domestic product (GDP) ratio and its road allocation to revenue ratio. This is done by expanding on a comparative analysis by Gomez and Vassallo (2014) on road financing approaches in Europe and the USA. Thirdly, from measuring the economic efficiency of the South African fuel levy through a productivity analysis by internationally comparing the fuel levy, reflecting on the vehicle population, annual distance travelled and fuel sale growth, investigating the relationship between the fuel levy and the fuel price, and then the fuel levy's revenue generation capability. This is done by seeking relationships between variables that influences the amount of fuel levy that is collected per vehicle that uses the road. The chapter concludes with a discussion on how South Africa could improve its current road funding policy.

Chapter 4 addresses research question 2, which continues to evaluate the need for DBRUC by assessing to what extent the current South African road cost recovery methods will be able to secure funding for roads in the future given the emergence of disruptive transport technologies and societal trends. The chapter starts by introducing the topic of estimating the impact of disruptive transport technologies and societal trends on road cost recovery methods while explaining its relevance to the study, stating the aim and objectives and outlining the main points of the research. Thereafter a brief review of the impacts and implications of disruptive transport technologies from an international perspective reflecting on its impact on road revenue forecasting, travel behaviour, municipal budgets and transport operator's revenue is provided. It continues by providing a description of the research methodology employed to address the chapter's aim which includes a time series forecast (ARIMA) and scenario analysis, outlining the objective of each method, describing the method design and limitation. This is followed by presenting the research results firstly from forecasting the revenue of South Africa's road cost recovery methods through a time series forecast (ARIMA) giving an account of fuel-based, vehicle-based and user-based road cost recovery methods' potential revenue by the year 2050. This is done by collecting historic revenue amounts of all road cost recovery methods and using a time series model (ARIMA) to forecast the possible revenue to be collected per road cost recovery method. Secondly from estimating the potential revenue impact of disruptive transport technologies and societal trends on South Africa's road cost recovery methods through scenario analysis where the effect of eight technological and societal transport changes which include vehicle fuel efficiency improvement, biofuel penetration, electric vehicle penetration, decrease in vehicle km travelled, adoption of greener vehicle technologies, vehicle parts usage efficiency improvement, decrease in vehicle ownership and lack of user compliance is investigated. This is done by reflecting on documented international technological and societal impacts on road cost recovery and subjecting the forecasted road cost recovery method revenue to such a scenario in the South African context. The chapter concludes with a discussion on how technological advancements must not be viewed as affecting the road cost recovery methods negatively but rather how the government can use emerging technologies to its advantage as a way to implement a user-pay principle policy for the road sector.

Chapter 5 addresses research question 3 which evaluates the appropriateness of DBRUC by assessing to what extent the South African road-funding framework reflect fair and efficient road user charges. The chapter starts by introducing the topic of deriving fair and efficient road user charges while explaining its relevance to the study, stating the aim and objectives and outlining the main points of the research. Thereafter a literature review is presented to explain the relationship between roads and economic and social development and unpacking the meaning of the user-pay principle. It continues by providing a description of the research methodology employed to address the chapter's aim which includes an impact assessment and the application of the social economic cost responsibility principle and PPP theory, outlining the objective of each method, describing the method design and limitation. This is followed by presenting the research results firstly from calculating the impact of the South African road-funding framework on road users through an impact assessment investigating the affordability of fuel in South Africa and the magnitude of transport costs on individual and household budgets. This is done by allocating the income of a hypothetical average South African, an average fuel-based motorist and an average electric-based motorist to expenditure needs with the focus on transportation costs. Secondly from deriving a short-run MSC-based road user charge through firstly applying the social economic cost responsibility principle to derive the marginal infrastructure cost, marginal congestion cost, marginal accident cost, marginal environmental cost and the total MSC for which road users is responsible and then secondly applying PPP to derive a variable MSC-based fee structure. This is done by estimating each MSC component in terms of an average charge per vehicle km drawing on cost estimates from the road industry, and then using European MSC estimates and converting this into values for South Africa that differentiates road user charges by vehicle type, area of usage, road type used and travelling conditions. The chapter concludes by recommending a way forward to address the current policy vacuum to regulate and ensure fair and efficient road user charges.

Chapter 6 addresses research question 4, which continues to evaluate the appropriateness of DBRUC by assessing to what extent South African road users view current, and proposed road cost recovery methods within the country's road-funding framework. The chapter starts by introducing the topic of gathering public opinion on road cost recovery methods in South Africa while explaining its relevance to the study, stating the aim and objectives and outlining the main points of the research. A review of international public opinion studies on DBRUC follows. It continues by providing a description of the research methodology employed to address the chapter's aim which include an online survey, outlining the objective of the method, describing the method design and limitation. Presenting the research results from collecting public opinion regarding the fuel levy and DBRUC follows through an online survey distributed through newspapers, large employers and social media. Various questions assessed road user's awareness, knowledge, perception, attitude, acceptance and favourability of the road cost recovery methods. The chapter concludes with a discussion on how to increase public acceptance of road cost recovery methods.

Chapter 7 addresses research question 5, which evaluates the practicality of DBRUC by assessing to what extent DBRUC are operationally feasible and economically viable in South Africa. The chapter starts by introducing the topic of testing a voluntary DBRUC in South Africa while explaining its relevance to the study, stating the aim and objectives and outlining the main points of the research. The key technical components required to implement a DBRUC system is presented thereafter. It continues by providing a description of the research methodology employed to address the chapter's aim which includes a vehicle tracking study and cost allocation analysis, outlining the objective of each method, describing the method design and limitation. This is followed by presenting the research results firstly from generating a DBRUC invoice in South Africa through a vehicle tracking study reflecting on the vehicle tracking data output, the data analysis and invoice compilation. Tracking a road user for a period of one week with the aid of an on-board vehicle-tracking device, processing the data and applying a flat rate per km was undertaken to calculate the road user's cost owed for using the road network. Secondly, calculating the revenue potential of a DBRUC in South Africa through a cost allocation analysis investigating the revenue from applying the fuel levy fee, revenue from applying the OReGO model, revenue from applying a variable short-run MSC based road user charge, revenue from applying the Freeman model and then comparing the different charging approaches' revenue. Tracking 18 road users for a period of one month with the aid of on-board vehicle tracking devices, processing the data and applying various rates per kilometre as calculated through four cost allocation methods was undertaken to calculate the road users' cost owned for using the road network. The chapter concludes with a discussion on future research required to develop a DBRUC system in South Africa.

Chapter 8 evaluates DBRUC as a road cost recovery method in South Africa given the study findings. The chapter starts by providing an overview of the study aim, highlight the research results and discusses the contribution it has made to the knowledge of road cost recovery and the use of DBRUC in South Africa. It continues by reflecting on the implications the research findings hold in terms of the implementation of short-run MSC-based charges, the allocation of road costs, the recovery of road cost through practical road cost recovery methods and the implications for road users and policy makers. The limitations of the research are discussed which is followed by some recommendations for future research, after which the study concludes with an overarching discussion on the future of DBRUC as a road cost recovery method in South Africa.

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Chapter 2. Assessing distance-based road user charges: A literature review

In the previous chapter, DBRUC was identified as a road cost recovery method, which could be implemented within the current South African road-funding framework to possibly secure funding from road users to meet the countries road expenditure requirements. However, objective research is required on whether this road cost recovery method should be adopted in South Africa. This study investigates this by evaluating the need, appropriateness and practicality of DBRUC using GPS-enabled vehicle tracking devices and a short-run MSC-based fare structure as a road cost recovery method in the South African road-funding framework. Chapter 2 aims to present a comprehensive literature review to provide a clear understanding of DBRUC and where it fits into the road-funding environment.

This chapter starts by placing DBRUC in context by reviewing how road cost is recovered by various practical methods. Problems associated with the main road cost recovery method used around the world, the fuel levy, and insight into possible solutions suggested by researchers are considered by delving deeper into the efficiency of this method. As the link between road cost recovery methods and road use are becoming less efficient the focus shifts to road pricing, and eventually leads to the argument for DBRUC which is viewed as a more direct method of charging individual road users to recover cost imposed on the road network. Following on this is a discussion on the DBRUC system through implementation and policy challenges identified by various academics, whereafter a quantitative account is given on the possible effects of DBRUC through system modelling. The literature review then presents numerous DBRUC experiments by means of vehicle tracking and public opinion studies and provides information of where and how DBRUC system or derivatives of this method have been wholly or partially implemented. Lastly, the chapter concludes with suggestions of directions for future research.

2.1 Introduction

It must first be understood that the concept of directly charging motorist for the use of roads, or any transportation route for that matter, is not a new system. Historically manifesting itself in the form of toll roads, this practice dates back millennia to the 7th century BC when travellers had to pay tolls for using a main road of about 500 km between the city of Susa (currently Shush in Iran) and Babylon (Iraq) during the Assyrian empire (Gilliet, 1990). The ancient Germanic tribes also employed this practice and charged travellers tolls for using mountain passes. In the middle ages, around the 14th century, river tolls were charged on boats at strategic points in the Netherlands. The border between Denmark and Sweden was once also tolled and delivered a large part of the king's income. During this time, modern European roads were originally constructed as toll roads in order to recoup the costs of building and maintaining the road network. Some of the most frequently used roads were repaired during the same era in England with revenue collected from tolls (Jordi, 2008).

Industrialisation in Europe during the 19th century required substantial changes to the transport infrastructure that included many new or significantly improved roads that were also funded from tolls. Built to provide a robust transportation network between England and Ireland, the A5 from London to Holyhead in the United Kingdom (UK) had a toll house every few miles. Road tolls were implemented in Europe in the 20th century to finance the construction of road networks and particular transport infrastructure such as bridges and tunnels. During this time, the State of Oregon in the USA was one of the first governments in the world to introduce a levy[1] on fuel sold at $0.01 per gallon as it was seen as an easy way to recoup road user cost at minimal cost to government. The rest of the world, including South Africa, soon followed suit. With the increase in vehicle ownership, other taxes and levies were also introduced, some as recently as the 21st century, where the recovery of cost from road users became a requirement and institutional practice to fund the ever-increasing demand for transport infrastructure.

This chapter aims to present a comprehensive literature review to provide a clear understanding of DBRUC and where it fit into the road-funding environment. This will be done by i) reviewing the existing knowledge and research on this method, and ii) identifying areas or challenges that require further research.

2.2 Distance-based road user charges in context

This section gives an overview of how road user costs are recovered, describing how the primary road cost recovery method used in the world, the fuel levy, is becoming increasingly inefficient. Two solutions to address this inefficiency is investigated which primarily focusses

[1] In the USA, the fuel levy is referred to as a tax. This is also true for South Africa, but in the country it is known as a levy. For consistency throughout the study a levy also means a tax in the USA context.

on increasing or earmarking the fuel levy. As there are numerous issues with these solutions the focus turns on road pricing which is seen as a more direct method of charging road users. It is within the context of road pricing that the argument for DBRUC is presented.

2.2.1 Road cost recovery methods

Since roads are non-pure public goods and the road market has natural monopoly features, it is contested that user fees play a part in road funding. The funding by means of general tax revenue has its merits and is highly popular with financial authorities around the world, but it is best suited for pure public goods (Naude, 1996). As a result, road cost recovery must be built on the theoretical premise that users of scarce resources should pay for the use of set resources (Pigou, 1912). Various taxes, or rather revenue sources, exist to secure funding for road construction, maintenance and upgrades, and can be grouped broadly into seven categories, which can be employed by governments as potential practical road cost recovery methods. These categories includes:

1. General revenue sources such as government allocations, subsidies, earmarked funds and loan funds;
2. Revenue from the public through ballot initiatives and public-private partnerships;
3. Taxes on the local community that includes property and land taxes, service charges, local sales and fuel levies, and utility taxes;
4. Taxes on employers or businesses through company car taxation, car parking space tax, business property tax, corporate profits tax, road transport business tax and payroll tax;
5. Taxes on location, entailing toll systems, parking charges, supplementary licensing and restricted area licenses;
6. Taxes on vehicle ownership listed as import duty on vehicles, excise tax on vehicles, vehicle licence fees, insurance taxes, turnover taxes, transfer taxes, axle or wheel tax and miscellaneous charges such as registration fees, drivers' licence fees, weighbridge fees, roadworthy test fees and permits; and
7. Taxes on vehicle use, which involves the fuel levy, tyre tax, levies on vehicles' spare parts and lubricants, weight-distance charges, road maintenance charges and direct road pricing systems (Fowkes, Mackie, Nash & Whiteing, 1985; Freeman, 1982; Kane, Sabol & Puentes, 2015; Varma & Sinha, 1990) .

No combination of road cost recovery methods are set in stone and many governments from around the world evolve their efforts to fund transport infrastructure on a regular basis to secure funds for road construction (Garret, 2016). When choosing a road cost recovery method to employ, countries should consider the fact that they differ in terms of their characteristics. In the context of the conditions under which these instruments would be used, it is important that each country analyses different charging instruments (e.g. tolls, weight-distance charges, fuel levies and registration taxes etc.). Very often, the distinction between the user charging techniques of countries represents economic efficiency objectives, ease of collection, administrative expenses, prevention or evasion potential, and the political acceptability of different systems. Therefore, the most suitable system may differ from country to country (Bousquet & Queiroz, 1996). The fuel levy, which is based on petrol and diesel sales, remains the primary sources of transportation funding around the world (Dumortier, Zhang & Marron, 2017). However, due to inflation and improved fuel efficiency, the levy is becoming increasingly inadequate to maintain the transportation infrastructure.

2.2.2 The ineffective fuel levy

Although the fuel levy is a tried-and-tested road cost recovery method, it has long-term sustainability issues, has strong user opposition and is regressive in nature (AASHTO, 2014). Furthermore, fuel levies are calculated as cents per litre rather than as a percentage of fuel sales. This results in its value declining with inflation unless it is increased regularly (Victoria Transport Policy Institute, 2014). The charge assigned to fuel levies differs between countries and regions within a country mainly due to the reliance on road transport for commuting in certain areas given the magnitude of its public transport system. Countries with more adequate public transport systems tend to have higher fuel levy prices (UK) than countries that have a struggling public transport system (South Africa) (Henderson, 2002). This difference can lead to cross-border travel to buy fuel that is less expensive to use in an area where fuel is more expensive. Additionally, fuel levies do not make road users aware of their total cost of commuting. The situation leads to inefficient overuse of road infrastructure and does not price for congestion, which leads to travel delays and increased road user cost. Furthermore, this inability to set prices to the total cost contributed to urban sprawl while moving the road cost recovery model further away from the user-pay principle and polluters-pay principle (Coyle, Robinson, Zhao, Munnich & Lari, 2011). In some countries like the USA, the fuel levy is not adjusted annually, despite inflation and a huge increase in road construction costs (Jaffe, 2014a; Sorensen, 2013). A higher fuel levy raises the pump price of fuel, increases vehicle-operating costs and consequently raises the price of a wide spectrum of goods and services. This raises the consumer price index (CPI) for rural households, urban low-revenue households and high-revenue households by about 0.6%, 0.8% and 1.2%, respectively. However, as long as the money raised by the fuel levy is spent on road maintenance, the operating costs of vehicles will be reduced (Heggie, 2003). Many people do not understand what the fuel levy actually pays for. In addition to roads, it also funds bridges, tunnels, carpooling and clean air programmes, bicycle lanes, sidewalks, mass transportation systems and other projects that help move people from point A to B (McMinn, 2015). For road users driving often, road infrastructure seems free because most of these costs are absorbed on a per-trip basis. The result is often that driving appears much cheaper than it truly is, which encourages more people to drive and causes more congestion (Ng, 2017).

In recent years, several technological advancements and societal trends started to emerge that will have a direct impact on the productivity of the fuel levy. From a technological perspective, the market penetration of electric vehicles will see fuel sales, on which the fuel levy is dependent, decline due to the announcement by especially the UK and France to ban the sale of new petrol and diesel vehicles by 2040 (Ward, 2017). Manufacturers which include, but are not limited to, Tesla and Volvo are embracing this planned change to produce affordable electric vehicles with Volvo, stating that it would put electrification of vehicles at the core of its business from 2019, planning to sell 1 million electric vehicles by 2025 (Hajiamiri & Wachs, 2010; McGee, 2017). In addition vehicle fuel economy is ever increasing resulting in new vehicles sold using less fuel per km travelled (Kim, Porter, Whitty, Svadlenak, Larsen, Capps, Imholt, Pearson & Hall, 2008; Morris, 2006; Soltani-Sobh, Heaslip, Bosworth & Barnes, 2015; Victoria Transport Policy Institute, 2014). From a societal perspective, road users are bombarded by frequent fuel price hikes and as such have started to change their driving behaviour to curb the effect of the increasing fuel prices to save on fuel costs. This includes driving slower, driving less (which was observed during and after the Covid-19 pandemic), starting lift clubs and avoiding peak time traffic (Kruger, 2018).

Recently, revenues from fuel levies have been diverted away from the traditional road transport activities toward more general societal needs, such as deficit reduction. The higher the percentage of fuel levy revenue dedicated to general uses, the higher the absolute and relative burden on the lowest revenue households, and the more regressive the overall distribution structure policy is (Wiese, Rose & Schluter, 1995). In terms of revenue, the fuel levy is found to be more regressive than electronic tolling. Users in the lowest-income bracket pay 20% of taxes while contributing only 13% of freeway km. Drivers in the highest-income bracket pay 18% of taxes while contributing 23% of freeway km (Venter & Joubert, 2014).

Although it is uncertain by when the fuel levy will not be able to generate any further revenue, for now it is safe to say that the fuel levies can generate sufficient revenue for a few decades to come, but several more effective and equitable kinds of user fees must be prepared to be phased in (Wachs, 2009). The time should be used now to investigate new funding and cost recovery approaches that accommodates vehicles with any propulsion system and fuel efficiency level (Forkenbrock, 2005).

2.2.3 Solutions to the ineffective fuel levy

2.2.3.1 Increasing the fuel levy

Fuel levies on petroleum products are currently an important source of revenue for low-income countries, but international experience has shown that the price of these fuel levies should increase gradually as low-income economies develop (Bacon, 2001). However, the danger exists that if these taxes increase the relative prices of fuel, a too large difference between products can lead to fuel switching which can affect government revenue generation. These increases in the fuel levies coupled with monthly adjustments of the base fuel price could lead to travel behaviour change in road users that are not captive users (Dondolo, 2018).

Assessing the impact of a hypothetical 10% increase in the South African fuel levy imposed by South African provinces shows the welfare effects to be negative but very small. Efficiency and equity (poverty) marginal surplus burdens are quite low, indicating much smaller effects of the intervention on both financial activity and equity. In addition, a fiscal policy reform that increases the fuel levy by 10 percent is progressive as it has greater adverse impacts on higher revenue households than lower revenue households (Mahugu, Chita & Amuse, 2011). Similarly, a second study used a computable general equilibrium (CGE) model calibrated with a detailed social accounting matrix (SAM) to assess the impact of a 3% provincial fuel levy application in all provinces in South Africa. Results show that while the fuel levy effect is not drastic, it is big relative to the revenue increase anticipated. (Mcdonald, Reynolds & Van Schoor, 2006). Another study conducted by the Bureau for Economic Research (BER) at the University of Stellenbosch discovered that the additional tax would increase additional revenue to the region (R290 million in 2004 at the suggested original rate of 10c per litre) with no or minimal adverse effect on either the provincial or national economy. It could be concluded from the above assessment that a provincial fuel levy, if levied concurrently on all provinces, is unlikely to have a dramatic impact on the economy, but it still imposes expenses on the economy, as taxes are bound to do.

2.2.3.2 Ring-fencing the fuel levy

Adherents of the road fund system, that is, an off-budget fund, argue that earmarking:

1. Gives greater assurance of minimum levels of public service funding considered vital by governments;
2. Provides some funding stability, as variability can be implemented if the road budget is part of the normal budgetary process ;
3. Establishes a strong link between taxation and expenditure and can therefore give appropriate signals to the authorities for efficient resource allocation ;
4. It is based on the benefit principle; and
5. Is generally accepted by the public (Bousquet & Queiroz, 1996; Cloete, 1990; Hjelle, 2003) .

However, due to experiences in the Central African Republic, Colombia, Ghana, Mali and Zaire where earmarking has not succeeded, many countries and the World Bank, once enthusiastically in favor of earmarking for road spending, have now changed their position. The primary issues faced include:

1. Road funds will be eroded during periods of inflation if taxes are linked to the fuel prices and are set administratively;
2. When the Treasury experiences a financial shortfall, earmarked funds may be momentarily frozen and diverted to other uses or government and public companies may simply stop paying fuel bills and thus their fuel levies;
3. Even if road funds are adequate, there is no assurance that maintenance, rehabilitation and new investment will be efficiently allocated (Newberry & Santos, 1999).

Additionally, a general road fund system's greatest criticism is that it is not user-based. The fear is that this system may result in underinvestment or overinvestment and may not give users a suitable signal (Schank & Rudnick-Thorpe, 2011).

2.2.4 Road pricing

As road cost recovery methods are not as effective anymore because there is little relationship between road usage and the payment method, a move is required to be made towards charging road users directly for using road infrastructure. There are numerous methods that have been developed and have already been implemented that fall under the umbrella term of road pricing (Wilson, 2010). These include, inter alia, the terms tolls/tolling, road user charging, congestion pricing, congestion charging, heavy goods vehicle (HGV) charging, HGV tolls, electronic fee collection, electronic road pricing, electronic road user charging, time distance place charging, cordon charging, cordon pricing, mobility pricing, toll lanes, high occupancy/toll lanes, road charging, vignettes, electronic free-flow tolling, value pricing, area pricing, area charging, eco charging and access charging. In terms of terminology, the primary reason for such variation is that road pricing terminology generally combines purpose (e.g. congestion charging), geography (e.g. urban, cordon or region), technology (e.g. electronic free-flow or open) and vehicles charged (e.g. only HGV). Road pricing systems can be better understood by considering: i) geography (what part of a network is charged?); ii) vehicles (what portion of the vehicle fleet is charged?); iii) purpose (Why does the charge exist?); and iv) chargeable events (what causes charging liability?).

The aforementioned charges may be used primarily for revenue generation, usually for road infrastructure financing, or as a transportation demand management tool to reduce peak hour travel and the associated traffic congestion. The charges may also target other social and environmental negative externalities associated with road travel such as air pollution, greenhouse gas emissions, visual intrusion, noise and road accidents (May, 1992; Victoria Transport Policy Institute, 2018) . For example, the Singapore Area Licensing System and the proposed Hong Kong electronic road pricing system were designed specifically to reduce congestion. Early studies in London and elsewhere were also primarily concerned with congestion relief, although the environmental benefits were also considered. The Dutch Rekening Rijden proposals for the Randstad and those for supplementary licensing in Stockholm have been primarily focussed on environmental improvements, with some emphasis also on congestion relief and revenue raising for public and private transport infrastructure. The Norwegian toll roads in Bergen, Oslo and Trondheim have been specifically designed to raise revenue for new road projects and public transport investment. Meanwhile, more recent UK studies, such as that conducted in Edinburgh, have assessed road pricing as part of a package of measures designed to achieve a combination of efficiency, environmental, accessibility and equity objectives. May (1992) states that the Smeed report identified twelve criteria for the design of road pricing systems:

1. Charges should be closely related to the amount of use made of the roads;
2. It should be possible to vary prices for different areas, times of day, week or year and classes of vehicles;
3. Prices should be stable and readily ascertainable by road users before they embark upon a journey;
4. Payment in advance should be possible although credit facilities may also be permissible;
5. The incidence of the system upon individual road users should be accepted as fair;
6. The method should be simple for road users to understand;
7. Any equipment should possess a high degree of reliability;
8. It should be reasonably free from the possibility of fraud and evasion, both deliberate and unintentional;
9. It should be capable of being applied, if required, to the whole country and to a vehicle population expected to rise to over 30 million;
10. The system should allow occasional users and visitors to be equipped rapidly and at low cost;
11. The charge recording system should be designed both to protect individual users' privacy and to enable them to check the balance in their account and the validity of the charges levied; and
12. The system should facilitate integration with other technologies and particularly those associated with driver information systems.

Other countries employ road pricing of the urban area through a congestion charge, urban toll road, control and emission zone or parking pricing. Countries employing these methods include i) European countries which include Austria, Bulgaria, the Czech Republic, Hungary, Moldova, Romania, Slovakia, Slovenia and Switzerland; ii) Italy, specifically Milan; iii) Norway, specifically Fjellinjen; iv) Singapore; v) Sweden, specifically Gothenburg,; and vi) the UK, specifically London. Road pricing is most famously done through toll roads and toll lanes, which can have tollbooths or electronic tolling gantries. The following places have such examples: i) Atlanta, Georgia, USA; ii) Brisbane, Australia; iii) California, USA; iv) Dublin, Ireland; v) Hong Kong, China; and vi) Portugal. Various countries are busy with investigations into road pricing, which include i) New Zealand, specifically Auckland; ii) Australia; iii) Copenhagen; iv) Ireland, specifically Dublin; v) Finland, specifically Helsinki; vi) Netherlands; and vii) the USA, specifically Oregon and California.

Rouwendal and Verhoef (2006) state the economic theory behind road pricing dates back to Pigou (1912) and Knight (1924) who wrote their seminal contributions about the misallocation of resources that would result from free access to public roads (Morrison, 1986). The fundamental reasoning behind this phenomenon is a so-called external effect: if there is congestion, each trip on the road forces other users to slow down and therefore to have longer trip times. In the absence of a toll, a driver does not have to pay for the additional costs he imposes on others. When this cost is ignored, the market fails. The situation can be improved by corrective policy measures, a toll being the main example. The primary economic motivation for introducing road pricing is that it enhances economic efficiency. In a (Pareto) efficient situation, it is impossible to improve the welfare of one actor without decreasing that of someone else. A situation in which the external congestion cost is not internalised is not Pareto efficient: it is possible to improve at least one person's welfare without making any other person worse off. Here, a first problem arises: few people consider the introduction of road pricing as a possible means to increase their well-being. In part, this problem is associated with all taxes and tolls: people do not like paying them and tend to ignore those useful public goods and services that can be provided with the corresponding revenues. Nevertheless, there is another negative aspect that is specifically associated with road pricing. It can easily be interpreted as a tax on experiencing congestion. Few people enjoy driving under congested conditions and road pricing appears to make things even worse. It can be interpreted as paying (a toll) for an unwanted product (congestion). For these and other reasons, economists have a hard time explaining why road pricing would be socially advantageous (Hjelle, 2003).

User taxes have been recognised as "prices" charged for the use of roads and streets (Buchanan, 1952). Secondary road users should be required to pay less than primary road users per ton or passenger distance travelled. In general, users of urban roads and city streets should pay higher prices than rural road users. Heavier and larger vehicles should be charged higher rates than lighter and smaller ones because both the direct and indirect components of MSC are greater. Slower vehicles should, within limits, be charged higher rates than faster vehicles. This is because they add more to congestion and thus indirect costs. Vehicles known to travel more during congested periods should be charged higher rates. Users should be charged higher rates on weekends and holidays than during other times, especially the users of egress routes from urban communities. In urban areas, higher rates should be charged during rush hours than during other hours of the day. Prices charged to users must vary directly with distance travelled.

Since 1975, Singapore has priced vehicle entry into its central business district. The main purpose of this pricing has been to manage traffic volumes rather than the collection of revenue. Prices have been adjusted as traffic conditions have changed (Christainsen, 2006). Since Singapore had successfully implemented its Electronic Road Pricing system with smart card technology in 1998, technological breakthroughs will further continue to make this technology worthwhile on both economic and financial grounds (Hau, 2006).

Numerous technologies, among others, tolling systems have been deployed that rely on the Global Navigation Satellite System (GNSS) (Numrich, Ruja & Voß, 2012). In South Africa, a road-pricing approach, specifically the development of toll roads, associated with a road-user pay principle, was developed by the South African National Road Agency Limited (SANRAL) to compensate for the deficit where required (Brits, 2010). Together with the fuel levy and DBRUC, tolls can produce one third of total revenues generated (Plotnikov & Collura, 2016). The best scale depends on what other functions the technology can perform. The main technology categories are roadside-only systems employing digital photography, tag-and-beacon systems that use short-range microwave technology, and in-vehicle-only systems based on either satellite or cellular network communications. The best technology choice depends on the application (de Palma & Lindsey, 2011). Intelligent transport systems through a wide variety of technologies and applications can hold numerous benefits that can be grouped into five categories (Ezell, 2010). The first category includes advanced traveller information systems that provide drivers with real-time travel and traffic information, such as transit routes and schedules, navigation directions, and information about delays due to congestion, accidents, weather or road repairs. Category two includes advanced public transportation systems that apply intelligent transport systems (ITS) to public transit, so buses or trains can report their position to inform passengers of their status in real time. The third category includes advanced transportation management systems that consist of traffic control devices, such as traffic signals, ramp meters, dynamic (variable) message signs and traffic operations centres. Category four comprises ITS-enabled pricing systems that help finance transportation through, for example, electronic toll collection, congestion pricing, high-occupancy toll lanes and vehicle miles travelled (VMT) usage-based fee systems. Finally, category five includes cooperative vehicle-highway systems, such as vehicle-to-vehicle or vehicle-to-infrastructure integration, that enable connectivity and communication between vehicles and infrastructure, such as roadside sensors or traffic lights, or among other vehicles.

Economists, however, disagree about how to set tolls, how to cover common costs, what to do with any excess revenues, whether and how "losers" from tolling previously free roads should be compensated, and whether to privatise freeways (Lindsey, 2006). Marginal external cost pricing is a first-best benchmark policy, because it simultaneously provides optimal incentives both in the short run (that is, given the shape and position of the relevant cost and demand functions) and, probably even more importantly, also in the long run by optimally affecting those factors that determine the shape and position of the relevant demand and cost functions. However, this benchmark policy is hard to implement in reality, because of a variety of technical, political, social, psychological and institutional barriers.

The best way to implement MSC is through user charges (Krygsman, 2014). User charges are implemented by way of congestion tax. South Africa's future is to follow international trends and adopt road user charging which includes toll roads, congestion charging and weight-distance charges. The current public effort is aimed at determining how to operationalise MSC, that is, to determine the exact MSC and the technical means to collect the funds. Toll roads address many road-funding problems as they:

1. Provide stable stream of earmarked funds;
2. Can accelerate road funding for freeway;
3. Can approximate MSC the best;
4. Can reduce traffic congestion;
5. Can ensure less travel time variability;
6. Can reduce higher speeds; and
7. Can lower vehicle operating cost.

However, tolls are contentious because:

1. Toll collection can be very expensive and inefficient;

2. If sufficient number of other forms of road user charges exists to cover total road responsibility, there can be over-recovery or double recovery;
3. Collection costs can absorb up to one-third of revenues and revenue theft is considered to be comparatively easy;
4. Discriminate against people that live near the facility; and
5. Where the tolled roads are less congested than the parallel "free" roads, the traffic diversion resulting from the tolls increases congestion on the road system and reduces its usefulness.

Realistic second-best alternatives will normally only cover parts of the first-best incentives and will therefore often have to be combined in packages, so that the complete range of incentives is eventually covered (Verhoef, 2000). It is important to realise that MSC pricing is only one pricing principle, amongst several others, and not necessarily the best one. Other pricing principles include average cost pricing, Ramsey-Boiteux pricing, redistributive pricing and specific pricing. Each of these principles serves one desirable policy objective (Prud'homme, 2001). Most drivers do not want to pay for roads that are currently free and most elected officials are aware that drivers are voters and do not support congestion pricing. The absence of advocates is a far greater hindrance than the presence of opponents.

"We can eliminate every argument against congestion pricing, but if we do not create a strong political argument for it, we will never properly price our roads" (King, Manville & Shoup, 2007).

Distance-based road user charges directly charged vehicles for each km driven. This method is deemed the best solution to the problems associated with the fuel levy as it will not be influenced by technological and societal trends, will not be dependent on fuel sales, can be a progressive tax and can generate more revenue to keep up with road construction cost and taxes for actual road use. Furthermore, it can supplement and, in the future, even replace the fuel levy to provide sufficient revenue. It is a policy-sensitive alternative whereby if governments change the tax, it affects road users' behaviour. It is in theory, at least, relatively easy to implement and can inform road users of the road user costs they pay through an itemised road user charge monthly bill (Coyle *et al.*, 2011; Jaffe, 2015a). Numerous DBRUC studies and pilot projects are being undertaken around the world, each with different objectives and designs (Mileage-Based User Fee Alliance, 2015). In the USA, 26 states are involved in pilot projects, the amendment of legislation and the forming of local and international km-based road user charge consortiums (Slone, 2015). In Europe, this road use revenue model has been implemented in various forms for heavy trucks in countries such as Switzerland, Austria, Germany, Hungary, Slovakia, the Czech Republic and Poland (Mahendra, Grant, Higgins & Bhatt, 2011). Furthermore, France, Belgium and Russia all have freight truck-based systems under development. New Zealand applies a similar system to all heavy and diesel-powered vehicles (Road User Charges Review Group, 2009). Research on a DBRUC system in developing countries is currently in its infancy and is required to be explored. Dumortier (2016) state that in the long-run the USA should shift its road infrastructure funding away from fuel levies to an alternative system which, as most studies suggests, should be based on VMT. In the meanwhile, policy-makers at the state and federal level in the USA argue that plug-in vehicles should pay registration fees to compensate for the fact that those vehicles use the roads but do not contribute to their construction and maintenance.

2.2.4.1 The argument for DBRUC

The replacement of inefficient road cost recovery methods should, however, be accomplished with great care, ensuring that there is a direct relationship between road use and the cost paid (Forkenbrock, 2004). Already in 1982, Freeman (1982), in his seminal work on road cost recovery in South Africa, advocated for a weight-distance charge as a supplementary tax to the fuel levy. He subsequently argued that vehicle licence fees and property taxes that bears an indirect relationship to road use could compensate for the shortfall in revenue recovered from heavy vehicles and are more direct methods of charging road users. This approach thus builds on the user-pay principle of the fuel levy and improves on it by being more economically efficient, more socially equitable, more fair and more financially sustainable (Poole, 2013; Zhao, Guo, Coyle, Robinson & Munnich, 2014). However, weight-distance charge are not perfect or final answers to the problem of road cost recovery. Before automated recording, monitoring and billing became inexpensive and widely available, varying degrees of approximation to the ideal system were required (Fwa & Sinha, 1987).

It is, however, accepted that weight–distance charges are difficult to administer and have a high evasion rate (Martin, Bell & Walton, 2014). The insurance industry greatly facilitated this process towards a workable and relatively inexpensive system by assessing the distance of vehicle travel that has direct bearing on accident risk and subsequently insurance cost (Nichols & Kockelman, 2014). In this industry, it has been shown that charging road users a premium based on distance travelled can reduce extraneous driving by as much as 2.7%, reduce crash risks, insurance costs and other externalities (Hensher, 2009). By capturing these externalities, such as congestion, pollution and safety, it is able to charge road users for their full social cost of driving (Hensher, 2009; Jaffe, 2015b). Thus, DBRUC can be feasible, but, in its current state, it will cost more to collect the road user cost than the fuel levy will be able to collect (Buxbaum, Griffith & Opiola, 2014). Recent innovations in electronic toll collection (ETC) technology make it possible to apply distance-based charges on a system-wide basis. This technology is increasingly used for collection at bridges, tunnels and toll roads and could be used comprehensively to charge drivers for distance travelled, thereby replacing fuel levies. It can actually improve upon fuel levies, because fees can be varied according to the types of road and the level of congestion, two factors that affect the costs of road use. Electronic toll collection makes system-wide distance-based fees possible, because it is both less costly and less cumbersome than traditional toll booths (Hanak, 2009).

Furthermore, it is argued that the conventional 1% revenue collection cost of the fuel levy may be incorrect and closer to 5% due to indirect costs, taxes hidden in the revenue collection, evasions and fuel levy exemptions (Poole, 2013). Nonetheless, this method will provide a more stable revenue stream in the short term, although not collecting exponentially more. In addition, its revenue base will not be eroded in the long term due to technological innovations, as the fuel levy will, although its fare must still periodically be increased to account for inflation. This increase could increase social welfare more than the fuel levy (Berg, 1990; Langer, Maheshri & Winston, 2017). Subsequent to the revenue generation aspect of this road cost recovery method, it can add value to motorists through services such as automated parking fees and tolls, real-time routing assistance and alerts to safety hazards, and better data for planning and operations. A system of distance fees can accordingly generate a steady stream of detailed (and anonymised) travel data, including traffic volumes and speed across all links of the network (Sorensen, 2013). This system is also able to change driver behaviour by reducing peak hour traffic or encouraging the use of electric or hybrid vehicles (Jaffe, 2014b).

2.3 The concept of DBRUC

In recent years, innovation in technology has made charging individual road users for the distance they travel a practical endeavour without the requirement for large tolling infrastructure (Forkenbrock, 2004). By installing a simple on-board system device that is secure and capable of protecting the road user's privacy, the actual distance the road user travelled can be calculated and then an appropriate road user charge can be applied to the distance travelled in a specific region with the use of GPS technology. The road user charge can either be a flat fee, that is a set amount of money per distance of travel anywhere on the road network, or a variable fee based on time, congestion levels, road type, type of vehicle used and vehicle emission levels or a combination of these factors (National Surface Transportation Infrastructure Financing Commission & Atkinson, 2009). The road user charge can also vary according to the purpose it intends to fulfil such as charging private vehicle road users higher charges in congested metropolitan areas depending on the level of demand, while not charging public transportation services at all (DeCorla-Souza, 2008). The on-board system device stores a record of the road use charges that the road user should pay and periodically transmits this record to a data-processing centre, which in turn sends an invoice to the vehicle owner for payment. The funds collected can then be allocated to the region that is mandated with providing the infrastructure on which the vehicle has travelled (Moulineaux, 2017). However the system of DBRUC seems simple and straightforward, numerous implementation and public policy issues have been identified. These are discussed in the following two subsections.

2.3.1 Implementation challenges of DBRUC

The implementation of a DBRUC system, however, holds various challenges that should be addressed. These challenges include i) the intrusion of personal privacy, ii) the security and protection of the on-board system device and charging process, and iii) the accuracy and reliability of the GPS system (Forkenbrock, 2004; Sorensen & Taylor, 2005; Zabic, 2007). Focussing on policy and operational considerations, further challenges include iv) the provision of audible records to road users, v) the parallel operation of the fuel levy and the DBRUC system for a number of years as the vehicle fleet turns over, vi) the development and operation of a national billing centre that is efficient and secure and able to support millions of accounts, and vii) the capability to ensure various policy initiatives to be pursued by individual provinces and subsequent regions (Forkenbrock, 2005). Crucial to the system success are viii) the setting of efficient charges, ix) public acceptance, and x) political leadership (Balwani & Arch, 2008; Goodin, Baker & Taylor, 2009; Oh, Labi & Sinha, 2007). In terms of transition considerations from a fuel levy to a DBRUC system, six additional challenges should be addressed. These include xi) policy decisions that should drive technical approaches and solutions, xii) a national policy framework that should be in place to guide local area implementation decisions, xiii) the requirement for large-scale implementations, xiv) clear objectives, xv) a need for extensive outreach and education with users, policymakers and legislators, and xvi) revenue allocation (Coyle *et al.*, 2011; Robinson, 2010).

Several methodologies have been proposed to address some of the identified issues. First, personal privacy intrusion can be minimised by i) limiting the amount of telemetry data stored before it is reported by the on-board system, ii) encrypting any potentially sensitive data stored in the on-board system and communicated to the data-processing centre, iii) reporting data anonymously where possible, v) preventing unauthorised access to any potentially sensitive information stored at the data-processing centre and vi) enacting appropriate regulatory and statutory controls on the data-processing centre to minimise the potential for misuse of collected data (Forkenbrock, 2004). Second, system security and protection can be effectively dealt with when i) incorporating an independent, reliable and secure odometer signal as a validation method, ii) providing an additional, completely separate and independent verification of the actual vehicle odometer reading to the collection centre at periodic intervals such as at the time of license renewal or vehicle sale, iii) employing digital signatures to authenticate and validate all data uploaded from the vehicle to the collection centre, iv) checking at the collection centre for lack of reporting activity by vehicles for extended periods of time to identify potential cases of in-vehicle system disablement or failure, and v) employing standard best practices in the design and operation of the collection centre to minimise exposure to hacking and denial-of-service attacks. Third, GPS reliability and accuracy can be improved by i) using various types of software-based systems, such as dead reckoning and motion prediction algorithms, to provide backup information, and ii) increasing the number of satellites (Zabic, 2007).

2.3.2 Public policy challenges of DBRUC

Apart from the implementation challenges pertaining to DBRUC, there are numerous public policy challenges that should be taken into consideration. These challenges entail the general stance or course of action that governments take on particular matters. Firstly, these challenges entail moving towards a user-pay principle road-funding framework. How funding for roads is secured is dominated by political consideration and as such there is a strong drive towards having a road funding framework that incorporates the user-pay principle (Schank & Lewis, 2013; Williams, 1995). There is, however, a danger that this system could lead to inadequate funding if it is politically controlled and not market driven. Nonetheless, by structuring the DBRUC appropriately per vehicle class could encourage a move towards this principle and assigning user charges that are equal to the cost imposed on a particular vehicle and influence road users to travel differently (Forkenbrock, 2008). It is required that the market reflect external costs, where road users pay the true cost of their vehicle use decisions (Lemp & Kockelman, 2008). It is estimated that if DBRUC were too be implemented in the USA, vehicle usage levels might drop by 6%-10% in the short run to as much as 10%-29% in the end. However, this requires road user charges to be set equal to the cost of the resources consumed. This cost is generally referred to as short-run MSC (Heggie, 1994).

Secondly, the challenges entail the reduction of urban transport externalities. Road user charging improve air quality by limiting trip demand and reducing emissions (Namdeo & Mitchell, 2008). A study undertaken in the UK showed that DBRUC reduces citywide emissions by 10% under a 2 p/km charge (R0.36), 42%-49% under a 10 p/km charge (R1.79) and 52%-59% under a 20 p/km charge (R3.58). The rand value given here were calculated using the spot exchange rate on 25/06/2018. Furthermore, fiscal policies, such as fuel and emission taxes, and regulatory policies, such as standards for fuel economy, emissions and fuel quality, help control these externalities (Timilsina & Dulal, 2011). The additional taxes (levied on consumers by means of the vehicle emissions tax) will discourage higher fuel consumption or CO_2 emissions (Nel & Nienaber, 2012). The successful introduction of road user charges in London in 2003 has seen more metropolitan areas investigating its appropriateness as both a means to reduce traffic and as a means to raise additional revenue (Kocak, Jones & Whibley, 2005).

Thirdly, the challenges entail the design of the urban environment. A modified road user charge fee may assist to discourage urban sprawl and reward mixed-use development and other development near or within existing activity centres (Seggerman, Williams, Lin, Fabregas, Nelson & Nicholas, 2010). The fee will result in a more fuel-efficient vehicle fleet than the fuel levy, but will fail to target and ensure that the high mileage consumers drive with more fuel-efficient cars. Once this targeting effect is taken into account, fuel levies turn out to be a more effective instrument to reduce fuel usage (even if assumed that car usage is perfectly elastic) (Grigolon, Reynaert & Verboven, 2015).

Finally, the challenges include the requirement for increased road funding. Speaking mainly on the fuel levy, there is a general reluctance of voters or their elected officials to increase the levy to account for inflation and increasing fuel efficiency as this would put an additional cost burden on the general population. Such an increase or any new or additional road cost recovery method will be met with strong resistance (Sorensen & Taylor, 2005). This is amplified with the cost of collecting the road user charge. The reason for this is that the cost of collecting the fuel levy currently is relatively low compared to the cost of collecting DBRUC. This is mainly due to the cost of the on-board system and accompanying processing system for which the road user would have to pay (Rufolo, 2011). Road users also currently believe that they pay the full cost of the roads they use through current road cost recovery methods, such as the fuel levy, although this is not true (Dutzik & Weissman, 2015). Nonetheless, if weight information is to be incorporated in a DBRUC it could allow for better cost recovery (Conway & Walton, 2009). This is built on the premise that time of day or real toll variation can incentivise underutilised periods and recover costs for the use of a highly congested area.

2.4 Modelling the effects of DBRUC

Mitchell, Namdeo and Milne (2005) applied traffic assignment, pollutant emission and dispersion models to a major UK city to assess the air quality impacts of five road pricing systems. The systems were evaluated with reference to exceedance of air quality standards for six pollutants, greenhouse gas emission, redistribution of pollution (an environmental justice concern), and road network performance such as traffic speed and trip distance. This study shows that road pricing can significantly reduce emissions and improve air quality and that pollution redistribution, which is undesirable from a social justice perspective, is not a major concern.

Oh, Labi and Sinha (2007) used economic theory, travel demand and highway expenditure data from the State of Indiana as basis to establish efficient VMT fee rates under various expenditure and funding scenarios. The authors found that a VMT fee of $0.03 per mile, plus federal aid, would cover current expenditures for state-administered highways in the absence of any other revenue source and that a fee of $0.02 per mile would be sufficient if revenue from vehicle registration was maintained. To cover the expenditures supported only by state-generated funds, the fee would be $0.01 per mile with vehicle registration revenues and $0.02 per mile without.

Hensher and Puckett (2008) stated that freight transporters are less sensitive to a variable user charge of the same magnitude as a fuel levy. Their study investigated the potential influence of variable user charges in the freight distribution chain. Provided the road network can deliver the expected timesaving in line with the value of travel timesaving, the benefits to the system will follow, including sizeable additional revenue. The study found that the implied elasticity of a distance-based charge/km with respect to value of travel timesaving is 0.075, which is relatively inelastic. Thus, a 10% increase in the variable user charge leads to a 0.75% increase in the amount an individual is willing to pay to save one hour of travel time, with other conditions remaining the same.

Zantema, van Amelsfort, Bliemer and Bovy (2008) stated that the most common effects of a pay-as-you-drive strategy in the Netherlands are mode, trip-making and route shifts. The case study was modelled on a transportation model (INDY) that, simulated travellers' choice behaviour and calculated traffic flows, taking into account the eight different Pay-As-You-Drive (PAYD) strategies which included no PAYD all the way through to obligatory PAYD with time and road type differentiation. These traffic flows were used to calculate effects on traffic safety and other network measures, such as congestion and travel time. The authors stated that to improve traffic safety, the best strategy would be to differentiate premium to reflect safety, that is, higher fees for unsafe road categories and night-time driving, most effectively and apply it to all drivers. This way drivers will optimise their road use toward the lowest cost and highest traffic safety.

Tampere, Stade and Immers (2009) presented the results of a modelling exercise aimed at ascertaining the effects of road pricing on a large road network. For the study area, they chose an important part of the road network of Belgium, situated in the corridor between the main cities of Brussels and Ghent. Simulations were carried out using an elastic static traffic assignment method. The main objective of tolling, as considered in this study, is the maximisation of the social welfare gain. However, possible adverse effects of tolling on traffic streams were also investigated. The reduction of traffic caused by increased prices as well as route changes induced by tolls were considered, but some other effects, such as travellers changing their destinations or shifting to another mode, were not included. The welfare gain, for that matter, appears to be rather modest.

Zhang, McMullen, Valluri and Nakahara (2009) estimated the distributional impact of the state-wide VMT fee policy proposed by the Road User Fee Task Force (RUFTF) on individuals with different revenues and residential locations. The methodology employs both vehicle ownership and type choice models and regression-based vehicle use models. This study analysed the short-run and long run impact of a proposed flat $0.012 per mile VMT fee on revenue and spatial distribution in Oregon. The results show that the distributional effects of the VMT fees are small and thus should not be a hindering factor in the future implementation of the proposed VMT fees. A flat rate may be simpler than variable fee structures, but it will also create an incentive for drivers to continue using fuel-inefficient vehicles.

Balwani and Singh (2009) investigated the design aspects of universal distance-based charging systems and incorporated procedures in a detailed network supply model to represent how a range of different permutations of distance-based charges across a given network (charging regimes) affect route choice, travel characteristics and demand for road space. The results suggest that distance-based charging can reduce the number and length of trips, congestion, accidents and pollution, and provide net economic benefits and revenues. However, these benefits are not found to be uniform throughout the network. Their magnitude largely depends on the charge level, the hierarchy of charges across the network, and the difference between the charge levels.

Rosenbloom (2010) presented the major findings from a study conducted for AARP (formerly the American Association of Retired Persons) on the implications of various transportation financing strategies for older and retired people. The study found that almost all current and proposed financing models are or would be regressive and that many would have a limited relationship to the costs that users impose on the system or the benefits they receive from the system. The most important study finding is that there are more substantial equity concerns for older and retired people when less traditional definitions of equity are applied.

Sana, Konduri and Pendyala (2010) offered a broad examination of the revenue generation and social equity implications of a national distance-based user fee that could be substituted for all or part of the current fuel levy. It is found that modest distance-based fees of just $0.005 per mile to $0.01 per mile can offer revenue streams that replace current fuel levy revenue. In addition, the distance-based user fee system appears to have minimal, if any, differential affects across revenue classes. Thus, it eliminates any potential equity concerns that may arise from the implementation of such a user fee system.

McMullen, Zhang and Nakahara (2010) used both a static model and a regression-based model to assess the distributional impacts of a switch from a fuel levy to a VMT levy for the state of Oregon. Results confirm that a change from a fuel levy to a VMT levy would increase the regressiveness of an already regressive fuel levy system, but the impact would be very small. Contrary to expectation, results show that households in rural areas would actually benefit from a change in tax regimes from a fuel levy to a VMT levy. This is because on average, rural households own vehicles that give fewer miles per gallon even though they drive more miles than urban households do. The bottom line is that although such alternate structures may provide an incentive to purchase a more fuel-efficient vehicle; these policies have an even larger negative impact on those in lower revenue groups than a flat VMT levy.

Robitaille, Methipara and Zhang (2011) analysed the distributional effects of an increased fuel levy and vehicle distance fees by considering both their effectiveness in revenue generation and their equity for different population groups at the federal and state levels. Both horizontal and vertical equity are considered for age groups, revenue groups, ethnicity groups and geographic locations. The data set used to perform the analysis in this study is the 2001 National Household Travel Survey (NHTS), which is the most recent nationwide travel survey (at the time this study was conducted) that captures driver and household characteristics. To perform the analysis, it was required to create a model that would predict how drivers within a household would react to changes in tax policy. A multiple regression model with interaction variables to allow for the heterogeneous demand responses to policy changes was consequently developed. When the three policies discussed in this study are compared, the fuel levy increase is found to have the smallest average decrease in consumer surplus for households. The average loss of consumer surplus for the fuel levy increase is $104.38 per household. Increasing the fuel levy causes a total decrease of 2.5% in total annual VMT from this model and creates the largest disparity between different revenue, age and ethnic groups but reduces overall average consumer surplus the least. Converting to an equivalent VMT fee generates the same amount of revenue as the fuel levy but increases the reduction in household VMT to 3.0%. The flat VMT fee creates a larger decrease in consumer surplus, that is $105.33; consequently, the VMT fee will create a slightly (0.9%) larger loss of social welfare.

Guo, Agrawal and Dill (2011) using data from a pilot distance fee programme run in Portland, Oregon, explored whether congestion pricing and land use planning were mutually supportive in terms of VMT reduction. They examined whether effective land use planning could reinforce the benefit of congestion pricing and whether congestion pricing could strengthen the role of land use planning in encouraging travellers to reduce driving. Vehicle miles travelled data were collected over 10 months from 130 households, which were divided into two groups: those who paid a distance charge according to rates that varied by congestion level (i.e. congestion pricing) and those who paid a distance charge according to a flat structure. Using regression models to compare the two groups, they tested the effect of congestion pricing on VMT reduction across different land use patterns and the effect of land use on VMT reduction with and without congestion pricing. The analysis shows that the VMT reduction associated with a distance fee of which the rate varies by congestion (congestion pricing) was greater in neighbourhoods with denser and mixed-use development than in neighbourhoods with low densities and predominantly single-family housing. In addition, urban form variables explained more variation in VMT under the variable rate fee structure than under the flat rate structure, indicating that the role of land use planning in influencing travel decisions was strengthened by the congestion pricing rate structure. In summary, congestion pricing and land use planning are indeed mutually supportive.

Weatherford (2011) used data from the 2001 National Household Travel Survey to evaluate the distributional implications of replacing the per gallon federal fuel levy with an equivalent flat rate VMT fee of $0.01 per mile. The analysis indicates that VMT fees will be less regressive than fuel levies by shifting the burden of taxation from low-revenue households to high-revenue households. The results provide new insight into the transportation tax burdens of households at different stages of life and suggest that a VMT fee would further shift the tax burden from retired households to younger households with children.

Bolderdijk, Knockaert, Steg and Verhoef (2011) stated that pay-as-you-drive vehicle insurance seems a promising tool for improving traffic safety. Speeding is an important cause for young drivers' involvement in traffic accidents. A reduction in driving speeds of this group could result in fewer accidents. One way of reducing driving speed is offering explicit financial incentives. In collaboration with five Dutch car insurance companies, they tested the effects of a pay-as-you-drive insurance fee at driving speed. A group of young drivers could save money on their monthly insurance fee by keeping to the speed limit. Driving speed was monitored through GPS technology over the course of one year. Analyses showed that, relative to pre-measurement and post-measurement, as well as a control group, the introduction of a pay-as-you-drive insurance fee significantly reduced speed violations of young drivers.

Jia, Zhou and Rouphail (2012), by focussing on partially modelling driver response to VMT user fees, investigated the potential traffic mobility effects of such fees from a traffic operational point of view under user equilibrium conditions. Within a gap function framework (for describing the user equilibrium under different tolling strategies); a mathematical programming model was formulated to describe the route choice behaviour of travellers, using heterogeneous values of time in response to fuel and VMT user fees. The model was applied to a simple two-link corridor and to a real-world network to study the mobility effects of distance-based tolling strategies. A key finding was that the VMT user fee might serve as an effective tool to mitigate traffic congestion. There may be an optimal value of VMT user fee to optimise the system average travel time. However, the availability and the value of the optimal VMT user fee depended strictly on the characteristic of the underlying transportation network, such as alternative path lengths and total demand level. An appropriate VMT user fee may encourage travellers to switch from a congested to a less congested route and improve the system travel time. Therefore, a fixed VMT user fee is not advisable. Rather, a VMT user fee structure that is time dependent, or facility dependent, or both, is preferred, although it may result in some implementation challenges in real-world applications.

Zhang and Lu (2012) in their study computed a vehicle distance fee on the basis of the MSC of travel and internalises various externalities, such as congestion, infrastructure deterioration, pollution emissions and greenhouse gas emissions. Multiple regression models and discrete choice models were developed based on the 2009 National Household Travel Survey data to analyse the impacts of the proposed MSC vehicle distance fee on vehicle ownership, fuel efficiency, VMT, energy consumption, emissions and equity. In addition, the sensitivity of these impacts to exogenous fuel price volatility was estimated quantitatively. Results showed that with consideration of all the aforementioned externalities, the MSC vehicle distance fee by vehicle make and model would range from $0.08 to $0.09 per mile, which is much higher than the per mile equivalent of the current fuel levies (about $0.01 per mile). Household vehicle use behaviour was much more sensitive to the MSC vehicle distance fee than vehicle ownership decisions, with a significant (27.1%) reduction in VMT, but a minor increase in vehicle fuel efficiency (up to 4.2%). Nevertheless, the MSC vehicle distance fee can reduce energy consumption and pollution or greenhouse gas emissions by about a fourth.

Larsen Burris, Pearson and Ellis (2012) used Texas data from the 2009 National Household Travel Survey to consider the equity impacts of four VMT fee scenarios. Data were filtered and weighted to reflect results representative of Texas vehicle-owning households in 2008. Each scenario was run both statically and dynamically under the assumption that the VMT fee would replace the state fuel levy. Based on quantitative measures, the vertical equity of all proposed VMT fee scenarios and that of the current state fuel levy were similar. In terms of horizontal equity, Scenario 4 was designed to be inherently horizontally equitable charging different rates for travel on urban roadways and rural roadways corresponding to funding requirement associated with that roadway type. Scenario 3, which favoured fuel-efficient vehicles, was found to be the least horizontally equitable and caused rural households to contribute the highest percentage of revenue of all scenarios considered. All other scenarios were found to be more horizontally equitable than the current state fuel levy.

Frank and Kaniok (2013) argued that road pricing is an effective tool but that it would be more effective if charges were differentiated. A laboratory experiment employing a heterogeneous sample (n=155) examined the effects of differentiated road pricing systems on understanding and behavioural change intentions. A distance-based road pricing system with a fixed charge per km was on average ranked most preferable compared to several other conceivable road-pricing alternatives. Even though the sample showed a slight bias towards younger and more educated people, the results provide valuable and reasonable data in agreement with previous studies. Based on these results, three conclusions can be derived. First, if road-pricing systems were simpler and more comprehensible in design, the performance of people would be faster and more accurate. The structure of the pricing system is important in order to assist certain subgroups, especially the elderly. Second, a fixed-charge per km system is most preferred. Third, a gradual introduction of road pricing systems may increase understanding of charges. Users will then be more likely to respond appropriately to the system in adapting their travel behaviour.

Meurs, Haaijer and Geur (2013), employing the automobile market model Dynamo, assessed the effects of replacing car purchase and road taxes with CO_2-differentiated DBRUC in the Netherlands. The effects of this replacement on vehicle size and the composition of the car fleet were estimated, as were the effects on emissions and mileage. They concluded that distance-based charging systems can reduce CO_2 emissions and other traffic-related pollutants but can also have unintended impacts on the size, composition and environmental performance of the national car fleet (e.g. car ownership increases, fuel efficiency is reduced and emissions per km driven increases). These unintended effects occurred because households react more strongly to one-time fixed costs than to recurring variable costs and because car costs are reduced for households with relatively low car usage.

Zhong (2013) developed a perceived risk-based stochastic network marginal cost pricing (PRSN-MCP) model. The main finding was that ignoring the effect of travel time reliability and travellers' perception errors may significantly reduce the performance of the first-best marginal cost pricing tolls, especially under high travellers' confidence and network congestion levels.

Zhang and Lui (2013) evaluated the impacts of MSC VMT fees on travel behaviour, revenue generation, equity, pollution, and greenhouse gas emissions in Maryland and the surrounding states of Delaware, Pennsylvania, Virginia, and West Virginia, and the District of Columbia. Results showed that with consideration of all driving externalities, the MSC VMT fee for travel in Maryland during peak periods ranged from $0.002 to about $0.12 per mile and from $0.04 to about $0.45 per mile for cars and trucks, respectively. Compared with existing revenue policy, the MSC VMT fee could reduce overall VMT by 7.65% in the multistate region covered by the quantitative model and by 7.81% just in Maryland. Furthermore, air pollution and greenhouse gas emissions in Maryland could be reduced by 7.62% to 9.42% by pollutant type. Total revenue generation would increase by about 168% (including fuel levies and bridge and roadway tolls). With regard to revenue equity, the middle-revenue group would be hurt most (largest consumer surplus decrease), while the highest-revenue group would be hurt least.

Paz, Nordland, Vamisti, Khan and Sanchez-Medina (2014) evaluated the effectiveness and equity of a fee for VMT for passenger vehicles in Nevada. In the evaluation of the fee's effectiveness, the collection capabilities and the impact on the number of miles users drove were considered. Equity was evaluated by considering the impact of the VMT fee on various population groups based on socioeconomics, demographics, household type, location and ownership of fuel-efficient vehicles. To estimate the impact on various VMT fees, a linear regression model was developed with the use of data from the 2009 National Household Travel Survey. This model provided a method to estimate VMT in Nevada as a function of the cost to drive, among other characteristics. The effectiveness and the equity of two alternative VMT fees were compared with the existing fuel levy system. These fees were calculated based on the average fuel efficiency of vehicles in Nevada and the historical revenue from the state fuel levy. In general, a VMT fee of $0.03 per mile seemed to be more effective than both the existing fuel levy and a VMT fee of $0.03 per mile. Although the $0.03 per mile fee had a slightly greater impact on various population groups, its equitable distribution of the tax burden among 71.1%

of households created a small average cost increase of just 0.37% per household. Thus, a $0.03 per mile fee would provide the required revenue without significantly affecting Nevada households.

Mandell and Proost (2016) analysed the way in which countries with international and local truck traffic decide to switch from a simple fuel levy system to a dual system of fuel and distance charge levies. This approach showed that, in the absence of diesel cars, the gradual introduction of km charges would make fuel levies for trucks virtually disappear and lead to a system where truck use i) is levied mainly based on distance, ii) is levied too heavily, and iii) is levied where highest distance levies are expected in transit countries with a strong market position.

Han (2017) assessed the potential impact on the US economy of a hypothetical infrastructure investment programme funded by three alternative options: i) an increase in the federal fuel excise levy rate, ii) the introduction of a nation-wide VMT and iii) the introduction of a nation-wide vehicle weight levy, using the KPMG computable general equilibrium (CGE) model. To demonstrate potential applications of a CGE model for the policy impact analysis, detailed modelling results under the federal fuel excise levy funding option were first discussed. The CGE model's main macroeconomic impacts were then compared with those under the other two funding options. According to the current modelling analysis, the weight levy option is considered to have the least long-run impact on GDP. However, in terms of the private consumption and employment impacts, the fuel excise levy option is expected to have the least impact. This indicates that household consumption is sensitive to fuel prices, reflecting that the household sector comprise a relatively large share of fuel consumption. At the same time, employment results turn out to be more sensitive to the fuel excise levy option, indicating that business cost impacts of an increase in the fuel excise levy are more severe than the other two tax options. The VMT levy option is considered to generate slightly higher macroeconomic impacts than the other two options. This indicates that the fuel excise levy option and the weight levy option are expected to result in more severe adverse effects on the business sector than the VMT levy option.

2.5 Distance-based road user charge experiments

Stemming from the theory, the requirement arises to test DBRUC through practical implementation and importantly gauge road users' opinion on this proposed road cost recovery method.

2.5.1 Vehicle tracking studies

Abou-Zeid, Ben-Akiva, Tierney, Buckeye and Buxbaum (2008) argued that distance-based pricing is a public policy tool for managing automobile travel by giving more price signals with the result of different transportation decisions and ultimately less driving much like the pricing signals that home owners receive from their home utility bills. The Minnesota Department of Transportation designed and implemented a one year field experiment to assess the response of drivers to price signals (price elasticity) that are based on miles driven and the overall effect of the programme on vehicle km travelled and traffic congestion. The experiment recruited 130 households and assigned each to a control-only, experimental then control and control then experimental group that was subjected to pricing at different intervals during the period. Pricing was assigned randomly, ranged from $0.05 to $0.25 per mile, and varied subjectively for peak and off-peak travel respectively. Mileage was monitored through electronic devices called car chips and through odometer readings. The results showed an overall reduction in miles travelled when groups were charged on a per mile basis and, although statistically insignificant because of the small sample size, that the resulting percentage change in mileage was regressed against the percentage change in price and lifestyle variables, with the elasticity of peak-period mileage being negative. Of the experimental groups 31% indicated that their driving habits were affected by the pricing signals.

Rufolo and Kimpel (2008) demonstrated that it is possible to collect a distance fee to replace the fuel levy and that the system is compatible with continued use of the fuel levy for non-participating vehicles. The Oregon Department of Transportation tested a system to collect a vehicle-based distance fee as a replacement for the Oregon fuel levy. Devices with GPS capability were installed on participating vehicles to determine the location and time of vehicle travel. Midway through the study, vehicles were assigned to one of three groups: control, VMT and peak hour. The VMT group was charged a flat fee per mile travelled that approximated the amount of the state fuel levy then paid by the average vehicle and was given a credit for the amount of fuel levy included in the purchase. The peak hour group was charged a higher distance fee during peak periods and given a discount on the mileage outside the peak times of peak zones. The control group continued to pay the price, including the fuel levy at the pump as before. The VMT group showed a reduction in total mileage relative to the control group and survey responses indicated that people did change their behaviour even though there was little price difference. In particular, there was a significant reduction in peak hour miles per day and total miles per day for the peak hour group. Surprisingly, there was also a reduction in driving for the distance fee group, even though the distance fee was the same on average as the fuel levy that it replaced.

Kim, Porter, Whitty, Svadlenak, Larson, Capps, Imholt, Pearson and Hall (2008) stated that an electronic VMT-based fee revenue collection system is a technologically feasible replacement for the traditional fuel levy. Since 2003, Oregon State University in collaboration with the Oregon Department of Transportation and the Road User Fee Task Force has investigated a VMT-based alternative to the fuel levy. The design, development and testing of the VMT-based solution was broken into several phases, the last of which required the execution of a pilot test from 2006 to 2007 involving approximately 250 volunteer drivers. The main objective of Kim, Porter, Whitty, Svadlenak, Larson, Capps, Imholt, Pearson and Hall's (2008) study was to present the technology performance results of the VMT-based solution gathered during the pilot test and to share the lessons learnt from its subjective evaluation. It was demonstrated that the calculation and collection of a VMT-based fee could be implemented with no additional actions required from drivers or those who operate service stations.

Hanley and Kuhl (2011) presented initial results and conclusions from the National Evaluation of a DBRUC, a two year field study conducted by the University of Iowa Public Policy Centre. The study, which evaluated technical feasibility and user acceptance of distance-based charging as a potential replacement for the current fuel levy, was authorised by the 2005 Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users, which reauthorised federal transportation funding. Approximately 2 650 volunteers from 12 areas throughout the country participated in the study which concluded in July 2010. The system distance charges were totalled and apportioned to the federal, state and local levels with the use of on-board computers installed in participants' vehicles. The on-board computers contained GPS receivers with an associated geographic database to identify the taxing jurisdictions in which the vehicles travelled. The average participant drove approximately 9 000 miles during the study (10 months). The study totalled more than 21 million miles. Approximately 92.5% of all driven miles were successfully measured by both the GPS and the on-board diagnostics system unit (OBD-II). Of the miles driven without GPS, 6.9% could be reliably assigned to jurisdictions by using straightforward interpolation techniques. Approximately 0.6% of total miles driven could not be reliably assigned to a state or local jurisdiction. Participant attitudes regarding the system and the overall system of distance-based charging were assessed. At the end of the study, 71% had a highly or somewhat positive view, and 17% held a highly or somewhat negative view. Prior to the study, more than 60% held a neutral negative view of the system. Participants consistently, but to varying degrees, preferred audit ability, which consisted of receiving detailed monthly invoices, over maximum privacy protection.

Dijksterhuis, Lewis-Eans, Jelijs, de Waard, Brookhuis and Tucha (2015) stated PAYD insurance links an individual's driving behaviour to the insurance fee that they pay, making car insurance more actuarially accurate. The best-known PAYD insurance format is purely distance based and is estimated to reduce accidents by about 15%. However, these benefits could be further enhanced by incorporating a wider range of driving behaviours, such as lateral and longitudinal accelerations and speeding behaviour, thereby stimulating not only a safe but also an eco-friendly driving style. Currently, feedback on rewards and driver behaviour is mostly provided through a web-based interface, which is presented temporally separated from driving. However, providing immediate feedback within the vehicle itself could elicit a quicker and greater change in driving behaviour. To investigate this hypothesis, two groups of 20 participants drove with a behavioural-based PAYD system in a driving simulator and were provided with either delayed feedback through a website or immediate feedback through an in-car interface, allowing them to earn up to €6 extra. Results indicate clear driving behaviour improvements for both PAYD groups as compared to baseline rides and a control group of equal size. After both PAYD groups had received feedback, the initial advantage of the in-car group was reduced substantially. Taken together with usability ratings and driving behaviours in specific situations, these results show a moderate advantage of using immediate in-car feedback. However, the study also showed that under conditions of feedback certainty, the effectiveness of delayed feedback approaches that of immediate feedback as compared to a naïve control group.

Whitty (2013) evaluated the detailed results of the first six weeks of the Road User Charge Pilot Program (RUCPP) in the US, for which survey and other objective data are available. Based on survey feedback to date, users regard the system as acceptable because it protects privacy, offers multiple reporting and payment choices, and, above all, is easy to use. In particular, pilot participants found distance-reporting equipment easy to install, plan type selections easy to make, and account management and bill payment easy to complete. The distance-based road usage charge demonstrated in the RUCPP generated slightly more revenue than the fuel levy for participating vehicles. Distance-based charges can generate more revenue from highly fuel-efficient vehicles than the current fuel levy generates from highly fuel-efficient vehicles. The RUCPP demonstrated that distance reporting hardware is safe and, based on statements of distance reporting hardware vendors, resistant to tampering and fraud attempts. The RUCPP system performs well on a number of other system criteria: it is feasible, accurate, reliable, secure and open. The evaluation team drew the following conclusions from the results:

1. The RUCPP to date appears to have met its objectives to demonstrate an easy-to-use distance reporting and payment system complete with palatable choices administered in an open, interoperable fashion by multiple private sector vendors;
2. Results suggest that a road usage charge with an open system is feasible, and a private market exists for the provision of a range of services related to road usage charge collection and administration;
3. Giving participants a choice of road usage charging plans is possible and supports the success of the pilot based on participant feedback;
4. The perception of user privacy appears to be improved when Oregon Department of Transport (ODOT) does not operate the distance recording and tax processing systems;
5. $0.02 per mile was generally acceptable as a price point; and
6. The participants in the RUCPP generally perceive a road usage charge as being equitable.

According to Whitty and Imholt (2007), the Oregon Department of Transport launched a 12-month pilot programme in April 2006 designed to test the technological and administrative feasibility of this system. The programme included 285 volunteer vehicles, 299 motorists and two service stations in Portland. At the conclusion of the pilot programme, 91% of pilot programme participants said that they would agree to continue paying the distance fee in lieu of the fuel levy if the programme were extended state-wide. Congestion and other pricing options are viable. The study showed that different pricing zones could be established electronically and the assigned fees could be charged for driving in each zone even at particular times of day. This proves the distance fee system could support not only congestion pricing but also assessment and collection of local revenues and other zone-oriented features. Furthermore, the area pricing strategy applied in the pilot programme produced a 22% decline in driving during peak periods.

2.5.2 Public opinion studies

Acceptance of a GPS-based DBRUC is likely to increase as drivers become more aware of how the system works. This includes demonstrations of a working device and information about how the data will be collected and will likely increase the overall level of comfort (Nordland, Paz & Khan, 2013). Perceived invasion of privacy and out-of-pocket technology costs to vehicle owners reduce their willingness to support a distance user fee. Approximately 20% of respondents have no privacy concerns related to the ability of GPS devices to track their locations (Duncan, Nadella, Bowers, Giroux & Graham, 2014). In addition there is anecdotal evidence that younger individuals are more willing to share information about their location in the public domain (Duncan & Graham, 2013). Furthermore, DBRUC can achieve higher acceptability if road pricing systems lead to perceived personal benefits (Furst & Dieplinger, 2014). The real bonus, and effective selling point, will occur when drivers i.e. the public see real-time cost savings as a result of this road cost recovery method and understand the reasoning behind it (Hensher & Mulley, 2014):

1. The public wants to see value;
2. The public prefers tangible and specific rationales;
3. The public cares about the use of toll revenues;
4. The public learns from experience;
5. The public believes in equity and fairness;
6. The public wants simplicity;
7. The public uses knowledge and information when available; and
8. The public favours tolls if the alternative is taxes (Zmud, 2008).

It was found that in the USA, the population subgroups most likely to consistently support transportation taxes include young people, Democrats, drivers of fuel-efficient vehicles, and respondents who wanted to see the American government improve safety, expand transit, and improve maintenance (Nixon & Agrawal, 2018). With the current indirect system (cents per gallon at the pump, these transportation taxes are essentially hidden to most consumers in the price of fuel), most people do not know what they are paying now relative to what is being provided and, more important, what is required to achieve an effective transportation system. The direct user charge system being proposed has the potential to make the connections much more evident and thus improve the willingness of individual system users to pay their fair share of the cost. However, it will require education and communication to reach that point (National Surface Transportation Infrastructure Financing Commission & Atkinson, 2009).

Agrawal, Nixon and Hooper (2016) identified twelve qualitative studies conducted since 1995 that explore perceptions about distance fees. First, the data showed that the majority of the public does not yet support a distance-based user fee system. For example, across the 33 poll questions that asked about support for a distance-based user fee (without specifying that the fee would replace the fuel levy); mean support was only 24%, with a range from 8% to 50%. Related to the question of whether people support the general system of a distance-based user fee was the question of whether they support replacing the fuel levy with a distance-based user fee. Both the survey and qualitative studies found that participants saw no compelling reason to replace the fuel levy. The average support across the 23 survey questions that addressed replacing the fuel levy with a distance-based user fee system (which was presented as a hypothetical scenario) was 23%. Support ranged from 8% to 42%. The study results provide tentative evidence that distance-based user fee support might increase over time, especially if new pilot programmes or other activities familiarise people with the distance-based user fee system. The meta-analysis of survey data showed that mean support for replacing the fuel levy with a distance-based user fee increased slightly over time and surveys of participants in two distance-based user fee pilot programmes found relatively high support levels, suggesting that direct experience with a distance-based user fee noticeably increases support for these fees. The qualitative studies and media story analyses provide a rich and detailed picture of the factors that most likely influence the lack of public support for distance-based user fees. In a few cases, survey evidence indicated that these factors matter to the public at large.

Two prominent themes emerged. Privacy was the first prominent theme in both the focus group studies and media stories. A second prominent theme in the qualitative studies and media stories was fairness, with the distance-based user fee system framed as both fair and unfair. For example, many focus group participants were concerned that fuel-efficient vehicle owners would pay comparatively more in distance-based user fees than they pay under the fuel levy system, while owners of less fuel-efficient vehicles would pay comparatively less. On the other hand, these participants thought it was unfair that a switch from the fuel levy to a distance-based user fee would penalise those who were "doing their part" to protect the environment and reduce greenhouse gas emissions. On the other hand, some participants thought a distance-based user fee was fairer than the fuel levy because with a distance-based user fee all drivers, including drivers of fuel-efficient and alternative fuel vehicles, would pay similar amounts of tax to maintain roads.

Other discussions of fairness centred on the impact that DBRUC would have on lower-revenue drivers, rural drivers, truckers and commuters and whether an distance-based user fee system would allow some unethical drivers to cheat the system by avoiding payment altogether. The most common worries centred on distrust of either the technology to be used or the ability of government to administer a distance-based user fee programme. Respondents predicted that both factors would cause billing errors. One of these concerns focussed on the loss of the fuel levy as a policy tool to incentivise the purchase of fuel-efficient vehicles. Another concern was the challenge a household would face in paying the distance-based user fee if it were charged periodically in large amounts (compared with fuel levies, which drivers pay frequently in small amounts). Furthermore, distance-based user fees with a congestion-pricing component were often viewed as unfairly expensive for people with inflexible work hours. Finally, the relative complexity of a distance fee also emerged as an issue in the media stories and focus groups. If there is going to be a distance-based user fee, people would prefer a simple structure.

Woven throughout the discussion of these concerns was a general preference for raising the fuel levy instead of implementing a distance-based user fee. Not only did many participants believe that the fuel levy still performed adequately, they believed that it avoided many disadvantages of a DBRUC, from high administrative costs, privacy concerns, charging hard-to-pay lump sum amounts, to preserving cost savings for drivers of fuel-efficient vehicles. People also appreciated the simplicity of a fuel levy compared with the complexity of even the most straightforward distance-based user fee system. Benefits of DBRUC emerged as well. Some people liked that DBRUC could ensure that drivers of electric and fuel-efficient vehicles pay their fair share of road maintenance costs. Most study participants had no idea what fuel levy rates might be or how much Americans pay per year in fuel levies.

O'Mahony, Geraghty and Humphreys (2000) evaluated the potential user response to distance and time-based road pricing of a sample of individuals drawn randomly from a group of volunteers in Dublin. The road use pricing charge levels were selected to match the MSC of car transport, i.e. those costs not currently paid by the car user. Such costs include MSC of congestion, air pollution and noise. A significant reduction in the number of peak period trips was evident, of the order of 22%, resulting from trip suppression and transfer to other modes.

In terms of user response, there appeared to be a significant reduction in car use, specifically a 22% reduction in trips during the peak period. There were also some impacts on total car travel demand in the order of a 3.4% reduction in trips but in the case of the off-peak period, the individuals appeared to be indifferent to the charges. Fifty-five percent of the sample stated they were not in favour of road use pricing but 45% suggested that they were.

2.6 Distance-based road user charge implementation

Several countries have implemented DBRUC systems or are experimenting with pilot programmes. Several pilot programmes are underway in the USA motivated, in part at least, by the pressure in the National and State Highway Trust Funds to collect sufficient revenue from road users. The Oregon Department of Transportation launched OReGO on 1 July 2015 (State of Oregon, 2017). Oregon was the first state in the USA to implement a fuel levy and was the first state to investigate and implement pilot electronic road user charges. OReGO uses a funding model that applies a "user pays" principle to pay for the road network. Road users pay a charge based on miles travelled. Paying by the mile makes the relationship between road use and funding more visible to drivers, which can motivate some Oregonians to use alternative transportation (public transport or ride-share) more frequently. The pilot programme is a field trail with more than 5000 volunteers participating with their vehicles (cars and light-duty trucks). Volunteers are given the option to choose a mileage reporting option from two independent operators as well as the Oregon Department of Transport themselves. Currently, the State charges $0. 30 per gallon of fuel sold. It works on an average fuel efficiency of 20 miles per gallon resulting in a $0.02 charge per mile. Road use invoices are issued to volunteers on a monthly basis and indicate the fee to be paid for road usage after a rebate of the vehicles fuel levy already paid at the pump.

The California State Transportation Agency, through the California Department of Transportation, launched the California Road Charge Pilot Program on a state-wide level and charges road users a distance-based fee, which is also differentiated by time. The initial exercise ran from 1 July 2016 until March 2017 (State of Oregon, 2017) and the field trail involved more than 5000 volunteers participating with their vehicles. Various road charging methodologies were tested and volunteers were given the option to choose a mileage reporting option that suites them. These methods include i) a time permit that allows unlimited road use in California for a specific period of time, such as a year, month or week, ii) a mileage permit which is a set number of miles based on the volunteers' expected use of California's roads, iii) an odometer charge where payment is remitted after periodic manual odometer readings and iv) an automated mileage report. California and Oregon are currently investigating an intrastate road user charge system. Other states are also experimenting with the methodology, for example New Mexico's Taxation and Revenue Department launched the New Mexico weight-distance levy on a state-wide level based on a weight and distance system (New Mexico Taxation and Revenue Department, 2017).

In Austria, in 1997, the Autobahnen-und Schnellstraßen-Finanzierungs-Aktiengesellschaft (ASFiNAG) was commissioned by the Austrian government to collect tolls (ASFiNAG, 2017). ASFiNAG collect tolls for different vehicle types: i) car toll (a time-based toll sticker for vehicles with a maximum gross weight of up to 3.5 t), ii) Toll for heavy goods vehicles (GO-Box, a distance-based toll with microwave technology); and iii) special tolls referred to as section tolls. A Belgian concessionaire, Sofico, introduced Viapass on roads and urban roads in the Flemish region of Brussels and Walloon on 1 April 2016 on the basis of km charges (Viapass, 2017). When driving on public roads, all trucks with a gross vehicle weight of over 3.5t must be fitted with an on-board unit.

In the Czech Republic, the Ministry of Transport and the Roads and Motorways Authority launched MYTOCZ, a tolls and vignettes road user charges system, on highways and motorways from 2007 (MYTO, 2017). Each vehicle over 3.5t must be equipped with an on-board tolling unit that cannot be transferred to other vehicles in order to be able to pay tolls. The Hungarian government has appointed the National Toll Payment Services PLC (NÚSZ Zrt.) to implement HU-GO, based on an electronic range toll system, on its public road network from 1 July 2013 (HU-GO, 2017).

This non-exhaustive review of the literature illustrates that several countries are shifting towards weight/distance-based charges for road users, especially heavy vehicles (> 3.5), as experiments and pilot programmes are successfully implemented. Their experience indicates that the success and indeed acceptability of this road user charge system depend on some closely related characteristics. Firstly, the technology, (tracking, back-end and front-end), which is currently available to run such a system and is already in place and will only improve in the future, should be used. Secondly, users should be involved in the system design and testing as in the USA and the purpose and workings of the taxes should be explained and communicated. Thirdly, the system should be trusted with regard to the organisation collecting the data, the specific charge (road use fee), privacy and ethical considerations.

2.7 Directions for future research

This chapter discussed the existing knowledge on DBRUC. Notwithstanding the seemingly positive results of DBRUC as a road cost recovery method that fosters efficient, fair and equitable road use prices, numerous issues emerged. The first issue is that the focus of most studies on road funding seems to be the fuel levy. Although this is the primary road cost recovery method, it is not the only revenue source from roads. No study delves into the road-funding problem as a whole or give account of how much funding is collected, distributed or allocated. In addition, no studies gives account of the expenditure of the funding. It is further acknowledged that the fuel levy will realise declining revenues in the future. This leads to the second issue, namely the uncertainty about when this decline in the fuel levy revenues might occur and, subsequently, what effects new technology may have on current road cost recovery methods' revenue potential. The third issue is that although various costing structures are proposed for road user charges, no studies on DBRUC investigate what form such a fee structure should take. The fourth issue is that public opinion on DBRUC is limited in terms of asking stated preference questions to determine the extent to which DBRUC might be publicly accepted. However, no account is given of whether road users are completely aware or have adequate knowledge of different road cost recovery methods. There is also no account of what road users' perception of these methods is. Based on this review, three complementary lines of research are suggested: i) to develop a methodology to unpack a road funding framework in order to assess the complete requirement for alternative or supplementary road cost recovery methods; ii) to assess the appropriateness of DBRUC in a country's road funding framework; and iii) to test the practicality of implementing DBRUC with first-best MSC pricing.

The following chapter will evaluate the need for DBRUC by assessing to what extent the South African road-funding framework is able to secure funding for roads.

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Chapter 3. Understanding the South African road funding framework[1]

In chapter 1, the importance of the South African road network and the funding thereof was broadly discussed leading to an argument that the need exist to investigate alternative road cost recovery methods such as DBRUC. Guided by a theoretical framework regarding road cost allocation and recovery combined with current academic research on road funding, the study sets out to evaluate the need, appropriateness and practicality of DBRUC using GPS-enabled vehicle tracking devices and a short-run MSC-based fare structure as a road cost recovery method in the South African road-funding framework. In chapter 2, a comprehensive literature review was presented to provide a clear understanding of DBRUC and where it fits into the road-funding environment, discussing the existing knowledge and research on this system and identifying areas or challenges that require further research. Chapter 3 aims to address research question 1, which evaluates the need for DBRUC by assessing to what extent the South African road-funding framework is able to secure funding for roads.

The chapter starts by introducing the topic of understanding the South African road-funding framework while explaining its relevance to the study, stating the aim and objectives and outlining the main points of the research. Thereafter a review of literature pertaining to the history and evolution of road funding in South Africa and how the current policy framework is changing is presented. It continues by providing a description of the research methodology employed to address the chapter's aim which includes a budget analysis, comparative analysis and productivity analysis, outlining the objective of each method, describing the method design and limitation. This is followed by presenting the research results firstly from quantifying the South African road funding framework through a budget analysis, providing an overview of the South African road network and then giving an account of the collection, allocation, expenditure and the distribution process of funds in the South African road funding framework. This is done by means of reviewing government and road-related SOEs' financial documents. Secondly from comparing the quantified South African road funding framework internationally through a comparative analysis with reference to its road expenditure to revenue ratio, its road expenditure to gross domestic product (GDP) ratio and its road allocation to revenue ratio. This

[1] Sections of this chapter are contained in articles already published in a peer-reviewed journal and peer-reviewed conference proceeding (Van Rensburg & Krygsman, 2015, 2019c).

is done by expanding on a comparative analysis by Gomez and Vassallo (2014) on road financing approaches in Europe and the USA. Thirdly, from measuring the economic efficiency of the South African fuel levy through a productivity analysis by internationally comparing the fuel levy, reflecting on the vehicle population, annual distance travelled and fuel sale growth, investigating the relationship between the fuel levy and the fuel price, and then the fuel levy's revenue generation capability. This is done by seeking relationships between variables that influences the amount of fuel levy that is collected per vehicle that uses the road network. The chapter concludes with a discussion on how South Africa could improve its current road funding policy.

3.1 Introduction

Currently, the fuel levy is seen as the primary method for South Africa to collect revenue from road users. It is supplemented by vehicle-based and user-based charges that include, inter alia, licensing fees and toll charges (Van Rensburg & Krygsman, 2019a). The fuel levy is an indirect excise tax payable per litre sold at the fuel pump, and contributes around 5% to the national fiscus (fourth highest income source) (National Treasury & South African Revenue Service, 2015). The total collected for 2014/2015 was R48,5 billion, which was around R2.55 per litre of fuel and R2.40 for each litre of diesel sold (Engen, 2016; National Treasury & South African Revenue Service, 2015). This revenue has increased considerably to R3.66 per litre of petrol and R3.52 per litre of diesel, with an estimated total of R82.9 billion for the 2019/2020 financial year (Fin24, 2019; National Treasury & South African Revenue Service, 2019).

The fuel levy's popularity for the usage by governments is due to i) its simplicity, ii) its ease of collection, iii) it differs in the vehicle's nature, iv) it varies with the speed at which the vehicle travels and how it is driven, v) it is difficult to avoid, vi) the administrative costs are a very low proportion of the total revenue, viii) and it is difficult to avoid (Freeman, 1982). Likewise, the fuel levy is by no means a perfect cost recovery method as i) it is unable to recover sufficient revenue from heavy vehicles to compensate for the extra cost burden (maintenance, congestion and pollution) they impose compared to passenger vehicles and as such does not reflect actual cost responsibility; ii) it cannot be easily fine-tuned to encourage or discourage any particular vehicle type or to promote a social policy; and iii) its revenue yield depends upon the total rate of fuel consumption (Van Rensburg & Krygsman, 2015). Furthermore, there is no rationale for how the fuel levy, or other road cost recovery methods' charges, is calculated or any indication that it adheres to the user-pay principle as stated in numerous governmental reports (Van

Rensburg & Krygsman, 2019b). The level of the fuel levies and other charges is not calculated through scientific means, but rather as part of the fiscal policy of government, which in turn is determined by the national budget, funding growths and other macro-economic demands. These taxes and charges go to the National Treasury, other spheres of government and selected road-orientated SOEs, with the exception of the Road Accident Fund levy, which is ring-fenced. The National Treasury then allocates its revenue to provinces, districts and SOEs based on input from the National Department of Transport to which the National Treasury responds. It is argued, however, that the fuel levy was and remains an economically efficient way of collecting revenue from road users, as it is able to secure sufficient funds for all road-related expenditure programmes and that no other methods for recovering road costs are required (OUTA, 2015). Although the public and government are mostly concerned with the fuel levy, it is by no means the only way government recovers cost from road users through its road-funding framework. The fuel levy's value is often misrepresented and its allocation and purpose are often misinterpreted.

According to the South African Department of Transport's Roads Infrastructure Policy Framework Draft (Department of Transport, 2014), there are various policies that seek to provide for an effective, affordable and efficient road transport network. However, challenges that are impeding economic development and welfare gains in many areas of the road transport sector remain. These challenges include an increasing road maintenance backlog, limited funding to meet increased road network demand specifically in larger metros leading to congestion and significant civil opposition to new road cost recovery methods with specific reference to the e-toll system. Complicating the situation even further in South Africa is that the road industry, broadly defined as road users, infrastructure service providers, transport operators, government and SOEs, seems saturated with distrust, suspicion and untruths about road funding. There is no consensus in the South African road funding framework on which cost recovery methods to use, limited knowledge regarding what is collected from road users and non-users, confusion around how much funds are invested in the road network and a limited knowledge base to substantiate current road user charges. Within this environment, it is very difficult to implement any new road user charges or promote a sustainable road infrastructure funding policy.

There is a growing body of literature on road funding, both internationally and in South Africa in response, at least partly, to transport infrastructure investment demands, pricing of transport infrastructure and new technological trends that affect infrastructure demand and supply. A general review of this literature found that many studies are i) focussing on the long-term viability of the general fuel levy in the light of technological developments such as increased fuel efficiency and electric vehicles, ii) estimating the social cost of road use to ensure economic efficient pricing or iii) considering alternative cost recovery models and approaches such as distance-based charging via GPS to accommodate both these trends (Bousquet & Queiroz, 1996; Dutzik & Weissman, 2015; Freeman, 1982; Whitty & Imholt, 2007). In response to a growing public debate and public recognition of deteriorating transportation infrastructure, and the possible impact on economic performance, the United States Congress set up the National Surface Transportation Infrastructure Financing Commission to undertake an investigative and analytical effort to evaluate the financial crisis and make suggestions to resolve the increasing transportation infrastructure deficit (National Surface Transportation Infrastructure Financing Commission & Atkinson, 2009). Similarly, the European Union has taken a proactive interest in estimating MSC of transport, harmonising transport tariffs and funding interregional transport networks (Korzhenevych, Dehnen, Brocker, Holtkamp, Meier, Gibson, Varma & Cox, 2014) .

Despite an active public debate internationally and in South Africa on toll roads, fuel levies and other road use taxes, very little research has been undertaken in South Africa that qualify and quantify transport funding and more specifically road funding.

Therefore, this chapter aims to evaluate the need for DBRUC by assessing to what extent the South African road-funding framework is able to secure funding for roads. This will be done by i) quantifying the South African road funding framework through a budget analysis, ii) comparing the quantified South African road funding framework internationally through a comparative analysis, and iii) measuring the economic efficiency of the South African fuel levy through a productivity analysis.

3.2 Literature review

The literature review briefly discusses the history of road funding in South Africa and reflects on the current policy framework and proposed changes.

3.2.1 A brief history of road funding in South Africa

Before 1935, South Africa's road construction and road maintenance were the responsibility of provincial and local authorities who funded the infrastructure through local tax revenue (Floor, 1985). The national government was entrusted with the development of the rail system at the time to cater for freight (and to some extent passengers) transported over long distances. After 1935, it became the duty of the national government to finance and fund roads that were of national significance. Funds for this activity were sourced from an import tax on each litre of fuel imported (3 pennies per gallon) and paid into the newly established National Road Fund (Van Lingen, 1960). The National Road Fund was not ring-fenced and allowed for additional state contributions.

This fuel levy had to be increased numerous times over the next 40 years to sustain the pace of road construction and maintenance. Despite these increases, the fund experienced declining revenue from 1974 because of a reduction in fuel consumption due to international sanctions imposed on South Africa, a fast increase in construction costs because of inflation and high design standards (Floor, 1985). It was required to increase the allocation of the fuel tax to the National Road Fund, but for that purpose, the central government and other tax beneficiaries were not prepared to forsake any of their revenue. Due to the likely effect on the already high rate of inflation, the government was not prepared to raise the fuel tax. As a result, the commission began to seek other sources of revenue. In 1983, power to charge tolls authority was given to tackle these funding problems to fund new roads, or road improvements, on stretches of roads where there was an alternative path. The first toll road followed in June 1984 when the Tsitsikamma Toll road was opened to traffic (Floor, 1985). Since 1983, the National Road Fund was also funded by a dedicated ring-fenced fuel levy in addition to tolls. This ring-fencing was removed in 1988 as it was argued that earmarking reduced transparency, accountability and access to additional funds when required in addition to the requirement that arose for funding other expenditure programmes (Julies, 2014). Since 1988, the fuel levy revenue has been assigned to the National Revenue Fund, managed by the National Treasury, which can be used for road construction and maintenance, public transport support and overall government expenditure (National Treasury, 2014a).

At present, the fuel levy is still South Africa's main method to collect revenue from road users supplemented by vehicle-based and user-based charges that include licence and toll fees (Van Rensburg & Krygsman, 2019b). These taxes and charges accrue to the National Treasury and selected road-based SOEs, except the Road Accident Fund (RAF) levy, which is ring-fenced. Through the national budget process, a large number of public institutions plan, collaborate, negotiate and decide together on a comprehensive government-spending plan for the next three years. Given fiscal limits, resources must be allocated in the most effective way to meet the policy objectives of South Africa as a democratic state, as set out in the Constitution, the National Development Plan, Governments Nine Point Plan and government's Medium term Strategic Framework. The National Treasury subsequently allocates the revenue to provinces, municipalities and SOEs based on input from the National Department of Transport (NDoT) to which the National Treasury responds. It must be noted that there is no direct link between the road user cost recovered that accrue to Treasury and the financing and funding allocated to the road sector. The magnitude of the fuel levies, and other charges, is not the result of exact road user cost calculation but is mainly the outcome of the fiscal policy of government, which in turn is determined by the national budget, funding growths and other macro-economic demands.

None of the South African road policy documents other than the National Transport Master Plan (NATMAP) to an extent (Department of Transport, 2013), including the White Paper on Transport Policy, the National Land Transport Strategic Framework (NLTSF) and the NDP, is very specific on how to fund road infrastructure in the 21st century (Department of Transport, 2013; National Planning Commission, 2009; Republic of South Africa, 2017). The overall idea seems to be that the user of the road or infrastructure should pay for their use based on the user-pay principle. There is, however, very little evidence indicating how much users should pay, how they should pay or which changes in the institutional regime will be required to facilitate the user-pay principle.

3.2.2 The changing South African policy framework

Currently, proposed South African transport policy documents emphasise that the transport sector, specifically the road sector, is experiencing funding problems.

For example, the Draft White Paper on Roads Policy for South Africa (Department of Transport, 2018a) states the requirement for funding to expand and maintain road infrastructure. The Policy mentions a current road maintenance backlog of R197 billion and that traditional rates and taxes, especially the fuel levy, are becoming an unsustainable revenue source. As a result, the Policy proposes that the Department of Transport and National Treasury explore the full range of financial models available to enable increased funding. These include the fuel levy, vehicle licence fees, collaborating with the private sector, seeking revenue opportunities from existing assets and potentially other innovative funding sources. The adoption of the user-pay principle through tolling is also mooted, although the principle is not really elaborated. A toll regulator is proposed by the policy, as part of the Single Transport Economic Regulator with the aim of creating an environment of coherence, independence, accountability, transparency, predictability and capacity in the development and approval of annual toll tariffs. Finally, the Policy states that government will not make additional funding available for the road sector and that more efficient expenditure in the road sector is required. To this end, the Policy states that road authorities will improve efficiencies in budget expenditure in the road sector by adhering to a "minimum level of service" and implementing a performance-based approach to administer grant funds.

The Economic Regulation of Transport Bill, published for comments in 2018, aims to "consolidate the economic regulation of transport within a single framework and policy, to establish the Transport Economic Regulator, to establish the Transport Economic Council" and will, importantly, administer price regulation in the transport sector (Department of Transport, 2018b). An independent strategic transport economic regulator will, as one of the functions, determine price controls and regulate tariffs for transport facilities and services based on fair and equitable pricing principles. The Bill acknowledges that South Africa has important economic infrastructure, including roads, rail, ports and airports, and that this infrastructure should be funded to stimulate the economy. The Bill says that a regulated entity's price control may include a schedule of tariffs, charges, fees, tolls or other amounts that may be imposed by the regulated entity for the use or access of any transportation service or facility provided by the regulated entity. While tolls and road user charges, such as heavy goods vehicle charges, will be subject to price regulation, the fuel levy, or taxes imposed by the National Treasury, will fall within the jurisdiction of the regulator.

Lastly, the Draft Revised White Paper on National Transport Policy (Department of Transport, 2017) supports promoting a sound transportation infrastructure economic base through suitable funding sources. This policy document refers to the different types of infrastructure and how they differ in their suitability and economic viability for cost recovery by charging users and/or direct private sector investment. Distinction is made between infrastructure for social access, requiring government funding or subsidy, infrastructure suitable for indirect user charging, such as fuel levies, license fees, tax on fares (however not reflecting on the long-term viability of the various charging models) and, finally, infrastructure suitable for private sector investment and partnerships involving both public and private sector investments, for example toll roads.

3.3 Research methodology

In order to evaluate the need for DBRUC by assessing to what extent the South African road funding framework is able to secure funding for roads, a budget analysis, comparative analysis and productivity analysis was performed. The research methodology briefly provides an overview of each technique used, where after these techniques are discussed in terms of its objectives, the method employed as well as the limitations of the method.

3.3.1 Budget analysis

The purpose of the budget analysis is to understand how the South African government's money is being collected, managed and spent and whether the budget meet the governments goals in terms of road infrastructure funding.

3.3.1.1 Objective of method

The budget analysis intents to quantify the South African road-funding framework. Information on road funding and expenditure on roads, road user charges and taxes imposed on road users and vehicle owners is not readily available through one source in South Africa. The National Treasury and road-related agencies keep accurate records of all taxes and levies collected, including the fuel levy and Road Accident Fund levy as well as all the other taxes imposed on vehicle owners such as VAT. The compilation of a comprehensive record of South Africa's road funding framework's finances is required to objectively view and assess the level, magnitude and limits of funding for road infrastructure to portray a picture that is substantiated by audited financial facts. For this purpose, publicly available documents, which include budgeting, financial statements and reports from all three spheres of government, including the six road-related SOEs had to be assessed to gauge the extent of revenue collected from road users, its distribution, allocation and expenditure on road infrastructure and road-related operation and regulation activities.

3.3.1.2 Description of method

A budget analysis was performed to understand how and to what extent the government sources revenue from road users and to understand how this revenue is managed and ultimately spent, while consolidating the road sector's finances into a single report. For this purpose, numerous government acts, bills and policy framework documents were firstly assessed to determine which spheres of government are mandated with the responsibility to finance and provide road infrastructure and road-related operation and regulation activities in South Africa. This process identified the following role players who either collect or receive road-generated revenue or who are responsible for road expenditure, be it for road construction, maintenance, upgrades or road-related operation and regulation activities i) the national government, which included the National Treasury and the National Department of Transport, ii) Provincial government, which included all nine provinces in South Africa, iii) local government, which included eight metropolitan cities, 44 district municipalities and 226 local municipalities across South Africa, and iv) six SOEs, namely the South African National Road Agency, the Road Accident Fund, the Cross Border Road Transport Agency, the Driving Licence Card Account, the Road Traffic Infringement Agency and the Road Traffic Management Corporation.

Secondly, the sources that are used by all road-related entities in South Africa to collect revenue from road users were identified. A research paper from Stander and Pienaar (2000) provided a comprehensive framework of these sources of revenue. Each revenue source was then categorised by identifying the sphere of government or road-related SOEs that collects revenue from the specific source.

A review of each entity's publicly available policy documents, financial documents, budget reports and financial statements were undertaken to account for all road-generated revenue collected through the sources identified by Stander and Pienaar (2000). This was followed by tracing all road-generated revenue collected through all the role players' financial documents to assess their revenue's distribution to the point where it was spent on road construction, maintenance, upgrades or road-related operation and regulation activities. The expenditure was further divided into expenditure that was allocated or ring-fenced (from the source of revenue) for specific expenditure programmes, expenditure on all road infrastructure programmes and expenditure on road operation and regulation activities.

In order to present a comprehensive report on road funding in South Africa, the budgets and financial reports of all transport departments across all three spheres of government and road-related entities had to be examined. Only revenue and expenditure that had direct bearing on road infrastructure and activities, which included operational activities and regulation, were included. All other transport activities, such as maritime and aviation expenditure which also falls under the mandate of government, were disregarded. The five-year period between 2010 and 2014 was selected for analysis as this was after the world-wide economic recession experienced in 2008 and before South Africa experienced wide-spread public debate and backlash on the fuel levy and e-toll systems. This period also provided audited financial reports from all road-related agencies that could be used when this research started in 2015 / 2016. It was therefore decided to use financial records from this timeframe as a base period for analysis in the study, while updating and using future values when available for subsequent analysis during the course of this research.

3.3.1.3 Method limitation

A limitation of this method was the ability to verify all revenue and expenditure values calculated and the distribution process of the funds. No road authority was able to confirm or deny any statements made or did not respond to any request for review. Another concern is that most budget and financial reports noted in a statement by the Auditor-General of South Africa, that there were some financial irregularities. These irregularities, in 2019, started to emerge through the recent and current investigations into state capture in South Africa that are mandated to investigate corruption in government. Furthermore, the revenue and expenditure pertaining to roads are not clear in some of the budget and financial reports and the inclusion and exclusion of values, or their calculation, were left to the discretion and assumptions of the researcher. It is therefore acknowledged that some percentage of error might be included in the calculation of the values.

3.3.2 Comparative analysis

A comparative analysis was used to measure the financial relationship between road income and expenditure over a defined period while comparing these relationships with other countries.

3.3.2.1 Objective of method

The comparative analysis intents to compare the quantified South African road-funding framework internationally. The analysis envisaged to assess how South Africa's road funding methods compares with other countries, by the three ratios, i.e. i) the road expenditure to revenue ratio, ii) the road expenditure to GDP ratio and iii) the road allocation to revenue ratio to the ratios of each of the countries. This will show whether South Africa follows international trends or is above or below the norm.

3.3.2.2 Description of method

Following the assessment of the comprehensive financial reports, local road funding trends were then compared through a comparative analysis with selected countries, which included the USA, France, Spain, the UK, Germany and Switzerland, in terms of a road expenditure to road revenue ratio, a road expenditure to GDP ratio and road expenditure to allocated road expenditure ratio. This comparative analysis was based on the methodology from research undertaken by Gomez and Vassallo (2014) who investigated a comparative analysis of road financing approaches in Europe and the USA. The values calculated through the budget analysis provided sufficient data for the ratios to be calculated, where only the GDP of South Africa had to be collected. The ratios were calculated by dividing the total road expenditure by the total revenue collected in the road sector, dividing the road expenditure by the country's GDP and dividing the road expenditure that is allocated for specific purposes by the total revenue collected in the road sector for each year.

The study by Gomez and Vassallo (2014) included the comparison of six countries. This study will include South Africa as an additional comparison country. For the comparison of the road expenditure to GDP ratio, it was decided to also include, in alphabetical order, Australia, Austria, Belgium, the Czech Republic, Denmark, Finland, Hungary, Israel, Luxembourg, the Slovak Republic, Slovenia, Sweden and Turkey in order to provide a more comprehensive evaluation. Apart from Israel, South Africa is the only other country classified as a developing country by the United Nations classification system.

3.3.2.3 Method limitation

The limitation of this method was the periods of analysis of the different ratios that did not coincide. The study by Gomez and Vassallo (2014) only compared the period between 2004 and 2009. With the base period for this study given as between 2010 and 2014, it does not necessarily lend itself to direct comparison with the international calculated ratios although trends can be observed. This was due to the difficulty in assessing the total road infrastructure investments for all the countries for the period defined by Gomez and Vassallo (2014). An attempt was made to update these values when comparing the road expenditure to GDP ratio for these countries, but the accuracy is unknown as this study used a different source that collectively showed the road infrastructure investment and maintenance cost of the international countries. It must also be noted that each country incorporated into this analysis is in a different stage of development, and its road network, user base and road-funding policies vary accordingly.

3.3.3 Productivity analysis

The productivity analysis set out to identify areas for potential improvements and pinpoint areas of delays and interruptions that cause loss of productivity of the fuel levy.

3.3.3.1 Objective of method

The productivity analysis intents to measure the economic efficiency of the South African fuel levy. This method set out to assess the South African fuel levy's economic efficiency, while comparing it to other countries. This was done to place the fuel levy as a road cost recovery method in context within the South African road-funding environment and accurately report on its revenue-generating potential over the last decade.

3.3.3.2 Description of method

In order to assess the productivity of the fuel levy in terms of its economic efficiency, the fuel levy charge for both petrol and diesel was compared as a percentage of the fuel or diesel price per litre of fuel sold with selected BRICS[2] and OECD[3] countries. Different countries statistics, which include development stage, population size, GDP per capita, vehicles per 1000 people of the population, road density and fuel price were then compared to determine whether there is a relationship between the price of the fuel levy and its revenue potential and the characteristics of a country. The annual fuel levy growth was then considered in terms of the growth of the registered vehicle population, the annual km travelled in South Africa and the fuel volume sold to assess if the fuel levy is becoming less productive compared to other indices because it is directly linked to fuel sales. The growth of the fuel price was then compared to the growth of the fuel levy charge to express the relational growth as a percentage. The fuel levy-generated revenue was then calculated and percentage change to the subsequent year calculated to assess whether the annual percentage growth rate is declining. A productivity measure in terms of an equation was expressed to assess the long-term earning potential of the fuel levy.

[2] Brazil, Russia, India, China and South Africa
[3] Organisation for Economic Co-operation and Development

Although the comparative analysis compared South Africa mainly to countries from the European continent, it was decided to rather compare in this analysis the fuel levy to countries that more closely resemble the economic state of development of South Africa. For this reason, the fuel levy is compared to BRICS nations that include Brazil, Russia, India and China, but also include OECD countries that include Australia, New Zealand, Germany, the UK, the USA and Canada.

3.3.3.3 Method limitation

It is noted that some limitations to the productivity analysis exists. Firstly, there is the unavailability of data on the total km that vehicles travel in South Africa. This data was collected until 1990, but required a crude projection using rolling averages to present an estimated updated forecast. Secondly, it is unknown what percentage of the fuel levy revenue is rebated, especially in terms of the fuel levy on diesel and the amount of this fuel sold annually. This calculation was left out of the analysis and it was assumed that no rebate was involved. Finally, the composition of the South African vehicle fleet is unknown in terms of specific vehicles used on the roads other than in terms of broad categorisations and the specific number of km that each vehicle travels each year is also unknown. Thus, calculations were based on averages.

3.4 Research results

The results section firstly presents the findings from performing the budget analysis where the South African road-funding framework was quantified. A brief overview of the South African road network is provided where after i) the collection of funds from road users, ii) allocation of funds to roads, iii) expenditure of funds on roads and iv) the distribution process of funds are discussed. Secondly, it presents the findings from performing the comparative analysis where the quantified South African road-funding framework was compared internationally. Three ratios that include i) the road expenditure to revenue ratio, ii) the road expenditure to GDP ratio and iii) the road allocation to revenue ratio are discussed. Lastly, it presents the finding from performing the productivity analysis where the economic efficiency of the South African fuel levy was measured. Herewith i) the international comparison of the fuel levy is presented, where after ii) the vehicle population, annual distance travelled and fuel sales growth as well as iii) the fuel levy in relation to fuel price and iv) fuel levy revenue are discussed.

3.4.1 Quantifying the South African road funding framework

South Africa boasts the 10th largest road network and 18th largest paved road network in the world (Kannemeyer, 2013). The country has an estimated road network length of 750 000 km (2015), which consists of 158 124 km of paved roads and 591 876 km of gravel roads (Department of Transport, 2016). The South African National Roads Agency Ltd. (SANRAL) is responsible for 2.85% of the network (SANRAL, 2015a). Of the remainder, 36.48% of the network fall under the jurisdiction of provinces, 8.82% under metropolitan regimes, 34.26% under the jurisdiction of municipalities and 17.59% of all roads are not proclaimed. In 2014, the road network value was estimated between R1.2 to R2 trillion (National Treasury, 2015) .

While scientific evidence is scant, SANRAL has argued that the part of the national road network, which was older than its initial 20-year design life, increased in 2008 from 36% to 78% and that the current road maintenance backlog is estimated at R197 billion (Kannemeyer, 2011, 2014). The condition of the road network in South Africa differs from transport agency to road type. In 2008, 30% of the network was in bad to very bad condition, 30% in fair condition, and 40% in good to very good condition.

According to eNatis, there were 10.35 million self-propelled vehicles using the country's roads network in 2014 (eNatis, 2015). This translates into 191 vehicles per 1000 members of the population. From the available statistics, the annual growth in the vehicle population is estimated at around 4%. The combined fleet of vehicles travelled approximately 162.40 billion km in 2014 (Road Traffic Management Corporation, 2014), and the national road network maintained by SANRAL is estimated to have accounted for 30% of those km (SANRAL, 2015b). In terms of vehicles per capita, South Africa ranks 85th in the world. As a result, only a relatively small vehicle population, which affects the cost liability of users, serves the extensive road network. This discrepancy among the size of the network and supply and amount of vehicles representing demand means that the funding demand and allocation for roads (i.e. upgrades, maintenance and expansion) are proportionately higher than in countries that have a more balanced relationship between road users and roads. Thus, the fleet or group of road users should also be larger if the network is larger. If not, road operators will pay either proportionately more (in the case of fewer road users) or proportionately less for the network (in the case of more road users).

3.4.1.1 Collection of funds from road users

Because of owning and operating a vehicle, road users pay various taxes and charges. In 2014, the total amount for road users was R166.4 billion (Table 3.1). This can be divided into direct revenue, which refers to revenue derived from the actual use of the network and includes fuel levies. The fleet (size of the fleet of vehicles) and road usage (km of travel) influence these revenues. In contrast, the general tax relating to the ownership and sales of motor vehicles (number of vehicles sold and imported) is an indirect (shaded) revenue source. There is no connection between road use and indirect sources of revenue. Total direct sales generated, which were also referred to as highway sales in 2014, were R100.4 billion. The main contributions were the overall fuel levy, the Road Accident Fund levy, the Demand Side management Levy (DSLM), the pipeline levy, the tracer dye and custom taxes, and excise duties that contributed about 30% to the price per litre of fuel (2014). The fuel levy was the main revenue source followed by the Road Accident Fund levy.

Table 3.1 | Road-generated revenue

Revenue sources ('000)	2010	2011	2012	2013	2014	%	Collects
Fuel levy	R34 417 577	R36 602 263	R40 410 389	R43 300 000	R47 516 564	29%	National
Road Accident Fund	R14 474 058	R16 989 071	R17 380 217	R20 352 981	R22 457 948	13%	SOE
Fines/fees and permits	R9 011 537	R10 988 624	R12 933 722	R10 853 033	R10 678 864	6%	Provincial
License fees	R5 057 977	R5 953 006	R6 530 434	R6 765 016	R7 349 077	4%	SOE/Local
Toll fees: concessions**	R3 987 937	R4 605 700	R5 029 190	R5 420 129	R5 846 819	3%	SOE
Toll fees: SANRAL	R2 073 060	R1 987 379	R2 199 090	R2 759 839	R4 221 433	3%	SOE
CO_2 emissions	R625 891	R1 617 353	R1 567 382	R1 636 848	R1 684 160	1%	National
DSML****	R51 000	R53 000	R152 000	R140 000	R170 000	<1%	National
Pipeline levy (petroleum products)	R31 000	R32 000	R33 000	R35 000	R37 000	<1%	National
IP marker levy	R1 000	R1 000	R1 000	R1 000	R1 000	<1%	National
Custom and excise levy	R817 000	R847 000	R875 000	R922 000	R981 000	<1%	National
Tyre levy	R0	R0	R0	R0	R0	0%	National
VAT on vehicle sales	R28 197 380	R31 099 740	R34 993 000	R37 154 040	R37 893 660	23%	National
Import duties: vehicle	R10 442 000	R14 348 000	R18 702 000	R21 635 000	R22 567 000	3%	National
VAT on vehicle parts	R3 909 640	R4 126 080	R4 496 380	R4 788 700	R5 009 760	14%	National
TOTAL REVENUE ***	R113 097 057	R129 250 216	R145 302 804	R155 763 586	R166 414 285	100 %	
Direct revenue	R70 548 037	R79 676 396	R87 111 424	R92 185 846	R100 943 865	61%	
Indirect Revenue	R42 549 020	R49 573 820	R58 191 380	R63 577 740	R65 470 420	39%	

** This is an estimate based on Annual Average Daily Traffic and tariff.

*** Other revenue sources from road users include: i) developer contributions, ii) parking fees and permits, and iii) tyre tax (R500 000 000 in 2015).

****Demand Side Management Levy

(Sources: Department of Energy, 2013; SAPIA, 2014; Statistics South Africa, 2014, 2016; National Treasury, 2014a, 2014b, 2014c, 2015; Road Accident Fund, 2014; International

Transport Forum, 2015; Bakwena, 2016; SANRAL, 2016; Trans African Concession, 2016; N3TC, 2016; Road Traffic Management Corporation, 2016)

The national government collects 31% of the direct revenue, provincial governments 6%; SOEs 19% and local governments collected 4% as illustrated in the last column of Table 3.1. Direct revenue grew by 43% between 2010 and 2014. The fuel levy, the Road Accident Fund, license fees, toll fees by SANRAL and concessions related to toll fees grew by 38%, 55% 45%, 104% and 47% respectively. To put this in perspective, the vehicle population in South Africa grew by 17% between 2010 and 2014 while the average annual inflation rate was only 7% in this period (eNatis, 2015; Road Traffic Management Corporation, 2014).

3.4.1.2 Allocation of funds to roads

It is possible to allocate funds from the revenue generated by roads and other government sources for road construction and maintenance projects. This is known as allocated revenue, which is defined as the annual revenue devoted to road financing, regardless of whether or not it is devoted to specific road projects (Gomez & Vassallo, 2014). Allocated revenue in South Africa is distributed in the form of road infrastructure and maintenance grants to various transport authorities (Table 3.2). These grants are the Public Transport Infrastructure Grant, the Provincial Roads Maintenance Grant, the Infrastructure Overload Control Grant, a grant to SANRAL's Non-toll Network, a grant to SANRAL's Coal Haulage Network and SANRAL's Gauteng Freeway Improvement Project Grant. In 2014, South Africa allocated R32.5 billion towards the construction and maintenance of roads. The majority of these allocations (+/-70%) came from the national government and was distributed to SANRAL, the provinces and metropolitan areas. After the distribution of the funds, road construction and maintenance become the responsibility of the SOEs and other spheres of government to use the funds for the purpose it was intended. The largest share of the allocated revenue was for the Provincial Roads Maintenance Grant and the grant for SANRAL's non-toll network, which should be used to construct and maintain over 273 000 and 18 000 km respectively. Allocated revenue increased by 121.5% between 2010 and 2014.

Table 3.2 | Allocated revenue

Grants and toll revenue ('000)	2010	2011	2012	2013	2014
Toll fees: SANRAL	R2 073 060	R1 987 379	R2 199 090	R2 759 839	R4 221 433
Toll fees: Concessions	R3 987 937	R4 605 700	R5 029 190	R5 420 129	R5 846 819
SANRAL: Non-toll	R4 065 177	R5 262 566	R5 934 636	R6 394 541	R7 515 300
SANRAL: Coal haulage	-	R464 782	R667 959	R648 910	R665 498
SANRAL: Gauteng freeway improvement project	-	R5 750 000	-	-	-
Overload control	R5 390	-	-	-	-
Provincial road maintenance	R4 862 460	R6 389 635	R8 988 337	R8 696 210	R9 361 498
Public transport infrastructure	R3 699 462	R4 988 103	R4 803 347	R4 668 676	R4 968 029
Total	R18 693 486	R29 448 165	R27 622 559	R28 588 305	R32 578 577

(Sources: National Treasury, 2014a; SANRAL, 2015a)

3.4.1.3 Expenditure of funds on roads

The annual expenditure on roads involves both capital investment and maintenance grants for roads supported by the three spheres of government and SOEs (Table 3.3). During 2014, R49.2 billion was spent on road infrastructure, which included routine maintenance, upgrades and new construction. This amount includes the allocated revenue. Road expenditure increased by only 14.2% between 2010 and 2014 or on average 3.5% per year.

Table 3.3 | Road expenditure

Transport entities ('000)	2010	2011	2012	2013	2014
National Government	-	-	-	-	-
Provincial Government	R14 269 254	R15 993 253	R17 634 059	R18 571 254	R20 169 802
Municipalities	R9 893 480	R12 260 308	R12 181 889	R13 564 588	R14 507 056
SOE	R18 972 179	R15 852 104	R15 191 965	R15 253 520	R14 584 260
SANRAL	R13 523 456	R12 638 823	R12 881 594	R13 079 213	R12 850 991
SANRAL: concessions	R5 448 723	R3 213 281	R2 310 371	R2 174 307	R1 733 269
Total	R43 134 913	R44 105 665	R45 007 913	R47 389 362	R49 261 118

(Sources: National Treasury, 2014a; SANRAL, 2015a)

For the 2014-2015 financial year, R119.5 billion was spent on road network infrastructure, transport operations and regulation in South Africa. Of this amount, only R49.2 billion (Table 3.3) was spent on road infrastructure while the remaining R70.2 billion was spent on road operations and regulation, which include public transport subsidies. The South African National Roads Agency Ltd. and the provincial and municipal governments were responsible for the road infrastructure investment. All spheres of government and all the SOEs (SANRAL, Road Accident Fund, Cross-Border Road Traffic Agency, Driving Licence Card Account, Road Traffic

Infringement Agency and Road Traffic Management Corporation) contributed to the operational expenditure of R70.2 billion.

3.4.1.4 The distribution process of funds

For the 2014-2015 financial year, the South African Revenue Services (SARS) collected R49.4 billion from road users with the local and provincial government and SOEs collecting the remaining R50.5 billion to account for the R100.9 billion as shown in Table 1.1. This R49.4 billion represents roughly 5% of the National Government's total tax revenue for 2014 (National Treasury, 2014a). The National Department of Transport (NDoT) received a transfer of R48.7 billion from the National Treasury or roughly, 50% of what is collected from the road users (2014). Of this amount, the NDoT transferred R32.3 billion to the SOEs and the provincial and municipal governments for road infrastructure and road sector operational activities. This included conditional grants to the provincial (R14.1 billion) and the municipal governments (R5.9 billion) and SOEs (R12.3 billion) to be used for road infrastructure and road operations activities. The NDoT allocated the remaining R17.1 billion to other programmes, including rail and maritime transport, civil aviation and administration,

The Road Accident Fund (RAF) collected levies of R22.4 billion (in 2014) from road users in the form of a levy raised on fuel. As with other taxes, the RAF levy is paid to SARS, who transferred it to the RAF in accordance with provisions of the Customs and Excise Act, 1964 (Act No. 91 of 1964) and the Road Accident Fund Act (Act No. 56 of 1996).

State-owned entities and provincial and municipal governments may use their own revenue to fund road operation activities and infrastructure investment. Their own revenue includes tolls (R10 billion) in the case of SANRAL and the toll concessions and local licensing fees, parking and permit charges and developer contributions. In the case of provincial and municipal governments (R18 billion). Furthermore, the provincial and municipal government may also access loans, government grants and their equitable revenue share or their own receipts from non-transport-related activities (such as property tax) to fund transport infrastructure and operations.

For the 2014-2015 financial year, R119.5 billion was spent on road network infrastructure, transport operations and regulation in South Africa. Of this amount, only R49.2 billion (Table 3.3) was spent on road infrastructure while the remaining R70.2 billion (Figure 3.1) was spent on road transport-related operations and regulation that include public transport subsidies. The South African National Roads Agency Ltd. and the provincial and municipal governments were responsible for the road infrastructure investment. All spheres of government and all the SOEs (SANRAL, Road Accident Fund, Cross-Border Road Traffic Agency, Driving Licence Card Account, Road Traffic Infringement Agency and Road Traffic Management Corporation) contributed to the operational and regulation expenditure of R70.2 billion.

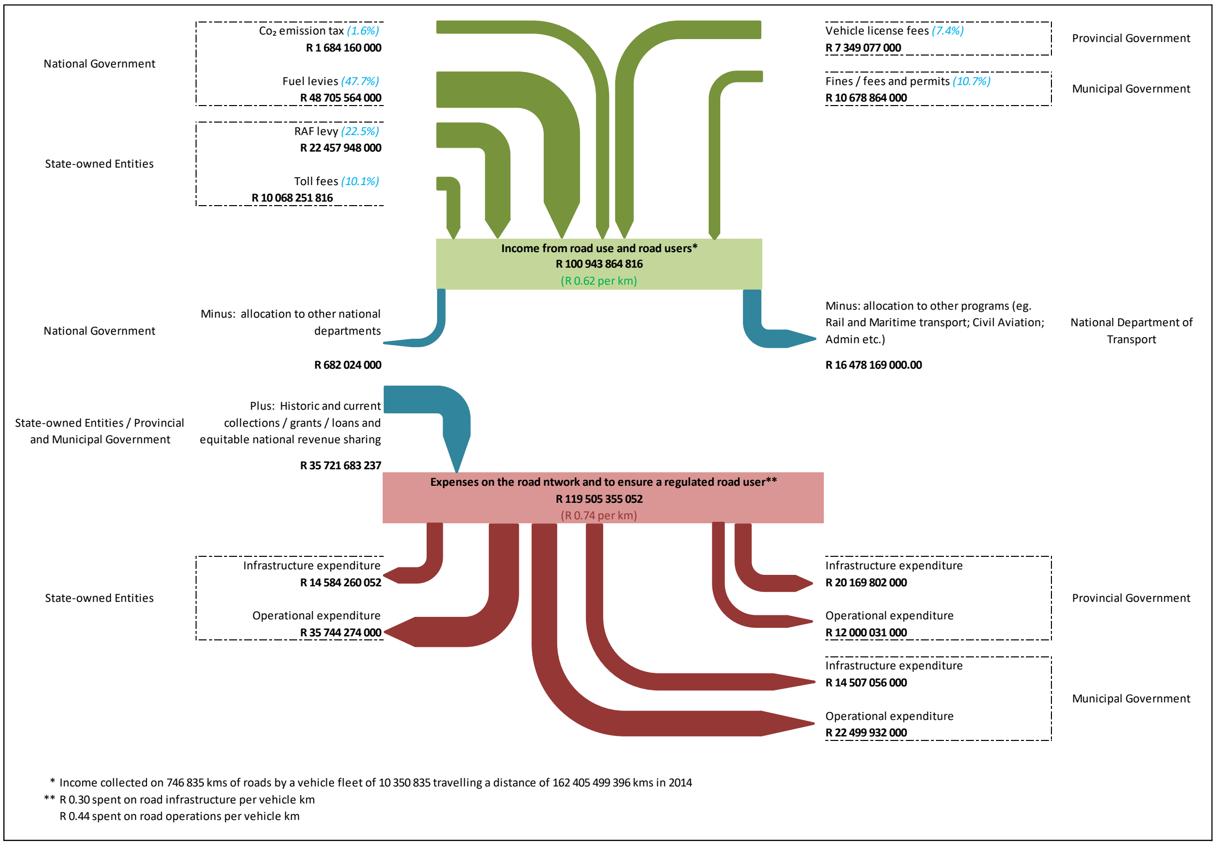


Figure 3.1 l The funding of roads in South Africa (2014)

In summary, during 2014-2015, R100.9 billion was collected through various charges, levies and taxes by all levels of government. A simple calculation reveals that assuming a vehicle fleet of 10 350 835 travelling a distance of 162 405 499 396 km, an average vehicle contributed R0.62 per vehicle km to the public treasury (Department of Transport, 2016; SANRAL, 2015a). SANRAL and the provincial and municipal governments spent R49.2 billion on road infrastructure (planning and design for road upgrades, maintenance and new construction). All authorities spent R70.2 billion on road operations and regulation resulting in R119.5 billion being spent on road infrastructure, regulation and operations. This resulted in an investment of R0.74 per vehicle km.

3.4.2 Comparing the quantified South African road funding framework internationally

Despite the active road funding debate, it is unclear whether South Africa spends comparatively more or less on its road network than its peers. Even with the above values, it is not known how South Africa compare. In order to put road funding in perspective, the country's road funding framework is compared to selected international examples. The South Africa road funding methods was compared with other countries, by calculating three ratios, i.e. i) the road expenditure to revenue ratio, ii) the road expenditure to GDP ratio and iii) the road allocation to revenue ratio.

3.4.2.1 Road expenditure to revenue ratio

The road expenditure to revenue ratio shows the money spent on roads (construction and maintenance) for every South African rand charged for road use. It is obtained by dividing road expenditure by road-generated revenue. Figure 3.2 shows the road expenditure to revenue ratio for selected developed countries (European countries and the USA) during the period 2004 to 2009 (Gomez & Vassallo, 2014) and for South Africa during the period 2010 to 2015. While the periods may not coincide, due to the unavailability of data, the general trend can still be observed.

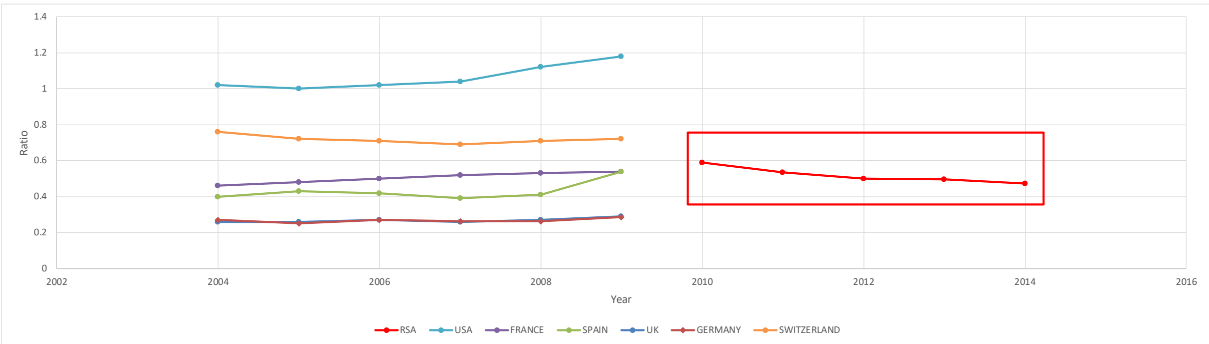


Figure 3.2 I Expenditure to revenue ratio for selected countries
(Sources: Own calculations; Gomez and Vassallo, 2014)

Three groups of countries can be distinguished: firstly, nations with a high commitment of road revenues (more than 60%) to road purposes, including the USA and Switzerland. Secondly, with an average expenditure rate of road revenues (between 40% and 50%), including France, Spain and South Africa; and thirdly, countries with low levels of expenditure (30% or below), including Germany and the UK. The third group still spend a lot on roads, but their taxes for road use is also very high (Van Rensburg & Krygsman, 2015). What is apparent from Figure 3.2 is that all these countries' road-generated revenue exceeds the revenue expenditure (the ratio is <1) with the exception of the USA. The USA has a ring-fenced highway fund to which all road-generated revenues are allocated. The Highway Trust Fund has been frequently under severe fiscal pressures and requires frequent federal bailouts. The USA fuel levy is of the lowest in the world and the UK and Germany have some of the highest fuel levies (Metschies, 2013).

3.4.2.2 Road expenditure to GDP ratio

The second ratio, road expenditure to GDP, shows the amount of money spent on road construction and maintenance for every South African rand the country generates through the production of goods and services, i.e. for every rand of South Africa's GDP. Gross Domestic Product measures a country's economic value. The sum of the market values or prices for all finished goods and services produced in an economy over a period is strictly a reflection of GDP. What is immediately apparent from Figure 3.3 is that South Africa, on average, spent a greater amount (1.2%-1.6%) of its GDP over the period 2010 to 2015 on road construction and maintenance than the selected developed countries (0.1%-1.4%) over the period 2004 to 2009. Numerous other OECD countries were included to compare South Africa over the period 2010 to 2015 showing the same finding of high GDP spending on road expenditure. Gomez and Vassallo (2014) stated that this ratio is not necessarily comparable since it can vary with population, area or population density. While the other countries in Figure 3.3 are all developed countries, the higher ratio may be reflective of South Africa's commitment to an infrastructure-led growth policy and investment in economic infrastructure. South Africa, however, does seem to allocate a reasonable share of its GDP to roads, but this share is steadily declining as other sectors of the economy receive greater political attention. The international average in 2014 was 0.67% of GDP spent, with South Africa at 1.29% (OECD, 2014).

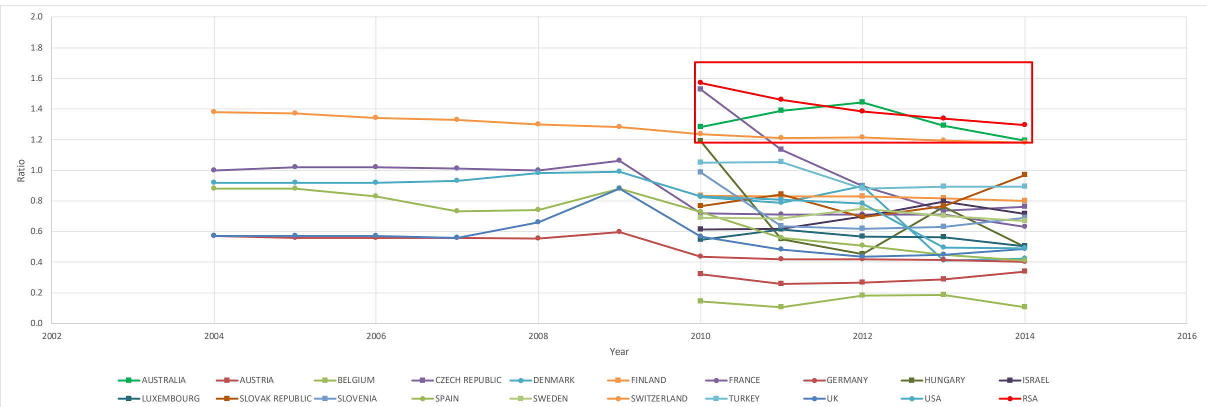


Figure 3.3 | Road expenditure to GDP ratio for selected countries
(Sources: Own calculations; Gomez and Vassallo, 2014; OECD, 2014)

3.4.2.3 Road allocation to revenue ratio

The road allocation to revenue ratio shows the share of road-generated revenue earmarked for road construction and maintenance projects (Figure 3.4). The USA has the highest road allocation ratio as it earmarks federal and state levies for road construction and maintenance projects. Switzerland mainly allocates vignette, fuel levy and heavy vehicle fees for this purpose. South Africa allocates between 0.3 and 0.4 of every rand collected to road infrastructure and maintenance. No single road-generated revenue method, except toll fees, are allocated directly for road construction and maintenance in South Africa.

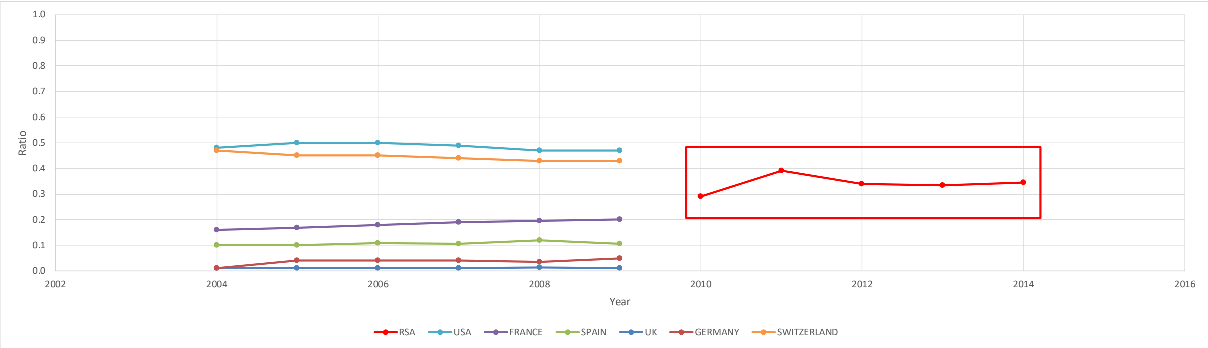


Figure 3.4 | Road allocation to revenue ratio for selected countries
(Sources: Own calculations; Gomez and Vassallo, 2014)

Although the periods of analysis do not overlap and they do not lend themselves to direct analysis, the findings remain valid.

3.4.3 Measuring the economic efficiency of the South African fuel levy

3.4.3.1 International comparison of the fuel levy

Table 3.4 compares the petrol and diesel fuel levy in US dollars for selected BRICS and OECD countries. Countries with a better public transportation system are generally more likely to have a higher fuel levy than those with a relatively poor system. In 2012, the petroleum fuel levy ranked eighth in South Africa, and the diesel fuel levy was 5th highest for the selected countries. However, the fuel levy in South Africa is quite low in absolute terms compared to the BRICS and the OECD countries.

Table 3.4 | Fuel levy per litre of petrol/diesel (2004 to 2012)

(Sources: Metschies, 2013; OECD, 2014; Engen, 2016)

		BRICS					OECD					
		South Africa	Brazil	Russia	India	China	Australia	New Zealand	Germany	UK	USA	Canada
2004	Fuel levy: Petrol	$0.10	$0.39	$0.10	$0.42	$0.03	$0.40	$0.32	$1.01	$1.11	$0.09	$0.23
	% of petrol price	26.3%	46.4%	18.2%	48.3%	1.9%	47.1%	51.6%	69.2%	71.2%	16.7%	33.8%
	Fuel levy: Diesel	$0.09	$0.05	$0.01	$0.18	$0.00	$0.39	$0.00	$0.85	$1.16	$0.13	$0.24
	% of diesel price	25.3%	10.2%	2.2%	29.2%	0.0%	47%	9.8%	65.9%	72.5%	22.8%	38.3%
2006	Fuel levy: Petrol	$0.10	$0.42	$0.11	$0.46	$0.03	$0.35	$0.40	$1.00	$1.09	$0.11	$0.28
	% of petrol price	17.1%	33.6%	14.1%	45.2%	1.9%	37.8%	40.9%	64.6%	66.6%	17.9%	33.0%
	Fuel levy: Diesel	$0.09	$0.03	$0.01	$0.10	$0.00	$0.35	$0.8	$0.77	$1.12	$0.13	$0.14
	% of diesel price	15.3%	3.4%	0.9%	13.5%	0.0%	37.4%	11.4%	55.9%	64.5%	18.2%	17.3%
2008	Fuel levy: Petrol	$0.11	$0.37	$0.10	$0.40	$0.03	$0.26	$0.42	$0.98	$0.79	$0.08	$0.21
	% of petrol price	12.5%	29.6%	10.8%	36.9%	1.5%	34.6%	38.6%	52.6%	61.9%	15.1%	27.6%
	Fuel levy: Diesel	$0.10	$0.03	$0.01	$0.10	$0.00	$0.31	$0.10	$0.80	$0.98	$0.11	$0.14
	% of diesel price	9.9%	2.8%	0.7%	14.7%	0.0%	33.0%	11.4%	51.3%	57.8%	14.0%	15.3%
2010	Fuel levy: Petrol	$0.15	$0.57	$0.15	$0.61	$0.04	$0.47	$0.66	$1.18	$1.22	$0.13	$0.38
	% of petrol price	21.5%	36.0%	17.4%	53.3%	2.3%	37.0%	44.8%	62.2%	63.8%	17.0%	31.6%
	Fuel levy: Diesel	$0.14	$0.04	$0.01	$0.13	$0.00	$0.48	$0.11	$0.91	$1.24	$0.15	$0.18
	% of diesel price	20.7%	3.2%	1.0%	16.3%	0.0%	38.9%	11.4%	54.3%	62.8%	17.6%	16.5%
2012	Fuel levy: Petrol	$0.18	$0.59	$0.15	$0.64	$0.05	$0.47	$0.71	$1.09	$1.29	$0.13	$0.39
	% of petrol price	17.9%	42.5%	15.3%	50.9%	2.1%	33.7%	40.3%	55.6%	59.5%	13.6%	29.2%
	Fuel levy: Diesel	$0.16	$0.04	$0.01	$0.15	$0.00	$0.54	$0.16	$0.89	$1.31	$0.14	$0.20
	% of diesel price	16.7%	4.1%	0.8%	17.6%	0.0%	34.5%	13.3%	47.5%	57.3%	13.4%	16.4%

Table 3.5 contains some general national statistics. South Africa ranks eighth out of 11 nations, ninth on GPD per capita growth, ninth on vehicle size per 1000 inhabitants, ninth on land size, fifth on road density and seventh on fuel price per litre (CIA, 2014; The World Bank, 2015).

Table 3.5 | Country statistics

(Sources: CIA, 2014; The World Bank, 2015)

		Classification	Population	GDP per capita ($) (2013)	Vehicles per 1 000 of population	Country size (km^2)	Road density (km/km^2)1	Fuel price 2014 ($/L)1))
BRICS	South Africa	Upper middle revenue	48 375 645	$6 886	165	1 219 090	0.5	$0.01
	Brazil	Upper middle revenue	202 656 788	$11 208	724	8 514 877	0.2	$0.02
	Russia	High revenue	142 470 272	$14 611	300	17 098 242	0.1	$0.01
	India	Lower middle revenue	1 236 344 631	$1 497	41	3 287 263	1.4	$0.01
	China	Upper middle revenue	1 355 692 576	$6 807	69	9 596 960	0.5	$0.01
OECD	Australia	High revenue	22 507 617	$67 463	703	7 741 220	0.1	$0.01
	New Zealand	High revenue	4 401 916	$41 824	708	267 710	0.4	$0.02
	Germany	High revenue	80 996 685	$46 251	588	357 022	0.1	$0.02
	UK	High revenue	63 742 977	$41 781	516	243 610	1.6	$0.02
	USA	High revenue	318 892 103	$53 042	786	9 826 675	0.7	$0.01
	Canada	High revenue	34 834 840	$51 964	607	9 984 670	0.1	$0.01

3.4.3.2 Vehicle population, annual distance travelled and fuel sale growth

Table 3.6 shows that the registered vehicle population of South Africa increased by 47.2% between 2003 and 2012 at an average annual growth rate of 4.4%. Per capita registered vehicle ownership increased over the same period by 60 vehicles per 1000 population.

Table 3.6 | Registered vehicle population, annual kilometres travelled and fuel volume sold (Sources: Department of Energy, 2014; Road Traffic Management Corporation, 2014)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2003 - 2012
Vehicles ('000 000) (#)	7.2	7.5	8.0	8.5	9.1	9.3	9.3	9.8	10.2	10.6	3.4
Change	-	292 641	492 010	573 715	523 715	236 388	40 722	484 170	363 652	417 559	-
% change	-	4.1 %	6.6 %	7.2 %	6.1 %	2.6 %	0.4 %	5.2 %	3.7 %	4.1 %	47.2%
% avg. annual growth	-	-	-	-	-	-	-	-	-	-	4.4%
South Africa Population ('000 000) (#)	46.4	46.4	47.0	47.6	48.2	48.9	49.5	50.2	50.8	51.5	5.1
Vehicles per 1000 of population (#)	150	160	170	170	180	190	190	200	200	210	60
Kilometres ('000 000) (km)	117 875	122 441	125 504	128 295	134 872	129 740	143.837	151 289	156 886	163 313	45 438
Change	-	4 566	3 062	2 792	6 577	-5 132	14 097	7 452	5 597	6 427	-
% change	-	3.9 %	2.5 %	2.2 %	5.1 %	-3.8 %	10.9 %	5.2 %	3.7 %	4.1 %	38.5%
% avg. annual growth	-	-	-	-	-	-	-	-	-	-	3.7%
Petrol ('000 000) (L)	10 4251	10 7661	10 9481	11 0301	11 3241	10 8471	11 0761	11 2071	11 7051	11 4601	1 035
Diesel ('000 000) (L)	5 0461	5 3701	5 6761	6 0911	6 8311	6 8321	6 2091	6 6911	7 3851	7 4091	2 363
Total ('000 000) (L)	15 4711	16 1361	16 6231	17 1211	18 1551	17 6801	17 2851	17 8981	19 0891	18 8701	3 399
Change	-1	6651	4881	4971	1 0351	-4761	-3951	6131	1 1911	-2191	-
% change	-1	4.31	3.01	3.01	6.01	-2.61	-2.21	3.61	6.71	-1.21	21.9%
% avg. annual growth	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	2.3%
GDP growth	2.91	4.61	5.31	5.61	5.51	3.61	-1.51	3.11	2.51	1.91	-

Table 3.6 shows also that the total distance travelled by the registered vehicle population between 2003 and 2012[4] increased by 38.5% at 3.7% on an annual average basis.

[4] Because there are no data for vehicle kilometres travelling during the periods 2009 to 2012, the figures were estimated to have averaged kilometres per vehicle between 2003 and 2008 and then increased with the number of vehicles between 2009 and 2012.

In addition, from 2003 to 2012, the volume of fuel used by the registered vehicles increased by 21.9% at an average annual rate of 2.3%. This refers to an increase in petrol by 1 035 million litres (9.9%) and diesel by 2 363 million litres (46.8%).

New technological developments increase the fuel efficiency of road vehicles every year. The average fuel efficiency[5] of all types of vehicles improved by 32% between 1970 and 2012, at an average of 0.9% per year (US Energy Information Administration, 2012). This meant that modern vehicles could travel 32% further with the same amount of fuel than the 1970 models and pay the same fuel levy. Fuel efficiency will also be affected by the market introduction of electric vehicles and biofuels. The Nissan Leaf, a fully electric vehicle serviced by nine charging stations (Nissan General Enquiries, 2015), was introduced to the South African market in 2013 and in recent years other vehicle manufactures have introduced their own models into the market.

Figure 3.5 shows the difference between the registered vehicle population, annual km travelled for the registered vehicle population and South African fuel sales. The percentage increases of passenger vehicles and km, respectively, are more than 25.3% and, therefore, more than the fuel sales growth of 16.6%. The levy on fuel is less productive than the other indexes because it is directly related to fuel sales.

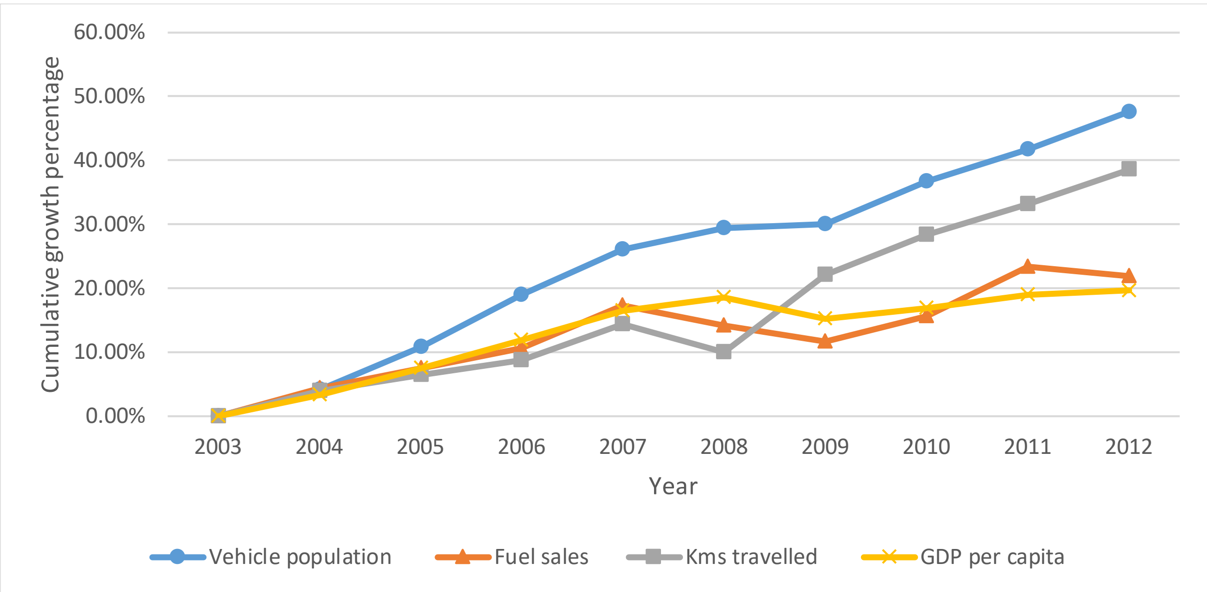


Figure 3.5 | Cumulative growth: registered vehicle population, annual kilometres travelled and fuel volume sold in relation to GDP

[5] The link between the travelling distance and the amount of fuel the vehicle is consuming.

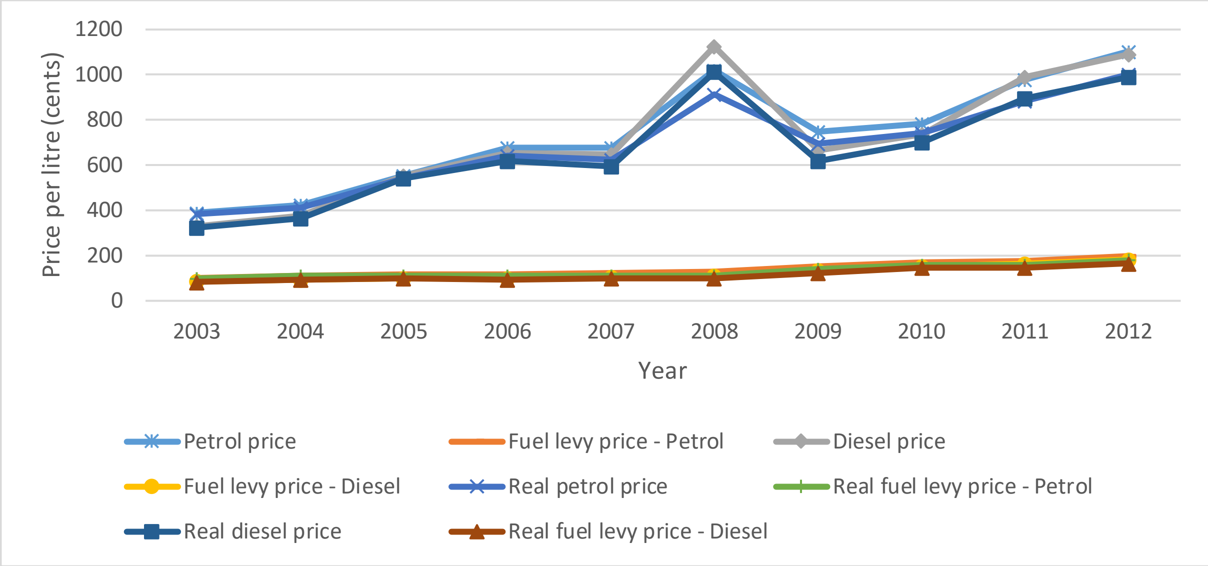
(Sources: Metschies, 2013; OECD, 2014; Engen, 2016)

The data shows the economy is stagnating (very low growth). Fuel sales just keep pace with GDP per capita (nominal value), but vehicle sales and km travelled increase more as people move away from public transport (and this in turn has implications for their disposable income that is getting less as they move away from public transport). All of this indicates that how much, and how taxes is collected, is very important. The need exists to move away from general increases in fuel levies to a user-pay system based on actual usage.

South Africa is not unique in the trend of population growth in the automotive industry, annual km travelled increases and an unproductive annual fuel levy. This phenomenon is also encountered in various countries such as the USA, Germany, UK, Sweden, Australia, New Zealand, and Singapore. Most of these countries seek viable alternatives to the decreasing sources of fuel revenue (Abou-Zeid, Ben-Akiva, Tierney, Buckeye & Buxbaum, 2008; Sorensen & Taylor, 2005; Whitty & Imholt, 2007).

3.4.3.3 Fuel levy in relation to fuel price

Figure 3.6 shows an increase of R7.14 (183%) and R7.63 (231%) in the price of petrol and diesel respectively between 2003 and 2012. The fuel levy for petrol and diesel increased by R0.97 (96%) and R0.98 (115%) respectively during the same period. This reflects an average annual increase of 7.1% and 8.1% for petrol and diesel respectively.



	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Petrol price	R3.90	R4.22	R5.33	R6.80	R.677	R10.20	R7.46	R7.83	R9.79	R11.04
Fuel levy: Petrol	R1.01	R1.11	R1.16	R1.16	R1.21	R1.27	R1.50	R1.68	R1.78	R1.98
Diesel price	R3.30	R3.75	R5.55	R6.52	R6.49	R11.25	R6.64	R7.36	R9.91	R10.93
Fuel levy: Diesel	R0.85	R0.95	R1.00	R1.00	R1.05	R1.11	R1.35	R1.52	R1.63	R1.83
Real petrol price	R3.84	R4.13	R5.41	R6.44	R6.22	R9.16	R6.93	R7.45	R8.84	R10.02
Real fuel levy: Petrol	R0.99	R1.09	R1.13	R1.10	R1.11	R1.14	R1.39	R1.59	R1.60	R1.79
Real diesel price	R3.24	R3.67	R5.43	R6.18	R5.97	R10.11	R6.17	R7.01	R8.95	R9.92
Real fuel levy: Diesel	R0.84	R0.93	R0.98	R0.95	R0.97	R1.00	R1.25	R1.45	R1.47	R1.66

Figure 3.6 I Fuel and fuel levy price per litre of fuel sold

(Source: Engen, 2016)

3.4.3.4 Fuel levy revenue

Table 3.7 shows that between 2003 and 2012, the fuel levy fund increased by R21 338 million (average of 10.8% per annum) because of more fuel that was sold and price increases.

Table 3.7 I Annual revenue from fuel levy

(Sources: Road Traffic Management Corporation, 2014; Engen, 2016)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2003-2012
Fund ('000 000)	R14 818	R17 051	R18 375	R18 885	R20 875	R21 360	R24 996	R28 942	R32 776	R36 156	R21 338
Change	R1 713	R2 233	R1 324	R510	R1 990	R485	R3 636	R3 946	R3 833	R3 381	-
% change	13.1 %	15.1 %	7.8 %	2.8 %	10.5 %	2.3 %	17.0 %	15.8 %	13.2 %	10.3 %	10.8%

Over the same period, average vehicle km travelled decreased by 1011 km (-6.2 %) and average vehicle fuel consumption decreased by 374 litres (-17.4 %) (Table 3.8). The vehicles' fuel economy improved by 1.5 L/100 km per vehicle over the period.

Table 3.8 | Average vehicle kilometres travelled and fuel consumption per vehicle per annum (Sources: Department of Energy, 2014; Road Traffic Management Corporation, 2014)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2003-2012	
Kilometres (km)	16 402	16 371	15 745	15 014	14 873	13 944	15 392	15 392	15 392	15 392	1011	-6.2%
Fuel consumption (L)	2 153	2 157	2 085	2 004	2 002	1 900	1 850	1 821	1 873	1 778	375	-17.4%
Fuel economy l/100km	13.1	13.2	13.2	13.4	13.5	13.6	12.0	11.8	12.2	11.6	1.5	-11.4

A valuable index for assessing the long-term potential for fuel levies appears to be the measurement of fuel levy productivity. The efficiency can be defined as a measure of economic output per input unit. This measure determine the additional revenue (R) generated by the vehicle km (inputs) between the current year of the investigation and the base year. The fuel levy (P) productivity is reflected in equation 1[6]:

$$P = \frac{\left(\frac{(PFC.PFL)+(DFC.DFL)}{100}\right)^{\text{current year}} - \left(\frac{(PFC.DFL)+(DFC.DFL)}{100}\right)^{\text{base year}}}{(VKT.RV)^{\text{current year}} - (VKT.RV)^{\text{base year}}} \qquad \text{(Eq 1)}$$

Where P = productivity of the fuel levy (R)

PFC = fuel consumed per annum – petrol (L)

PFL = fuel levy – petrol (c)

DFC = fuel consumed per annum – diesel (L)

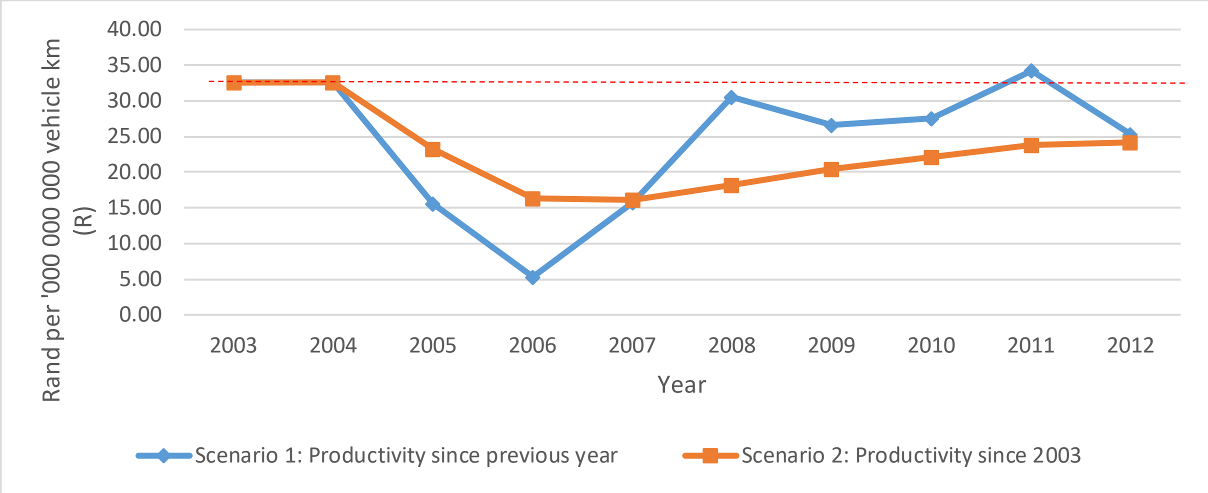
DFL = fuel levy – diesel (c)

VKT = vehicle kilometres travelled per annum (km)

RV = registered vehicle population (# vehicles)

Figure 3.7 produces two scenarios to illustrate the fuel levy's productivity. Scenario 1 calculates productivity from the previous year and, scenario 2 calculates productivity since 2003.

[6] All negative values must be positive until the outputs above the line are separated in the inputs below the line, because only the productivity value will be interpreted.



	Scenario 1: Productivity since previous year			Scenario 2: Productivity since 2003		
	Productivity (R)	Effect on revenue (output)	Effect on vehicle kilometres (input)	Value (R)	Effect on revenue (output)	Effect on vehicle kilometres (input)
2003	R32.55	+1	+1	R32.55	+1	+1
2004	R32.53	+1	+1	R32.53	+1	+1
2005	R15.64	+1	+1	R23.20	+1	+1
2006	R5.33	+1	+1	R16.32	+1	+1
2007	R15.69	+1	+1	R16.11	+1	+1
2008	R30.55	+1	-1	R18.17	+1	+1
2009	R26.54	+1	+1	R20.48	+1	+1
2010	R27.62	+1	+1	R22.07	+1	+1
2011	R34.21	+1	+1	R23.88	+1	+1
2012	R25.29	+1	+1	R24.09	+1	+1

Figure 3.7 | Productivity of the fuel levy

For both scenarios, the calculations reveal a decrease in additional fuel levies for each additional km of vehicle travel. It was about R7 for scenario 1 and R8 for scenario 2 between 2003 and 2012. In 2008, the fuel levy became most productive (scenario 1). In addition, the calculations show that the fund did not generate the same revenue as the red dashed line set in 2003, while the fund was increased in absolute terms. This level was only improved once in 2011 in scenario 1 when the fund increased by R34.21 per one billion vehicle km.

The levy on fuel should have increased by more than what it actually increased so that R32.55 per billion km in vehicles travel is maintained. This level of productivity will be improved at a rate shown in Table 3.9, showing the fuel levy projection.

Table 3.9 | Productivity projection of fuel levy

(Source: Engen, 2016)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Fuel levy: Petrol	R1.01	R1.11	R1.16	R1.16	R1.21	R1.27	R1.50	R1.68	R1.78	R1.95
Fuel levy: Diesel	R0.85	R0.95	R1.00	R1.00	R1.05	R1.11	R1.35	R1.52	R1.63	R1.83
Fuel levy: Petrol - projected	R1.01	R1.11	R1.24	R1.40	R1.56	R1.56	R1.85	R2.05	R2.12	R2.39
Fuel levy: Diesel - projected	R0.85	R0.95	R1.10	R1.23	R1.38	R1.40	R1.70	R1.90	R1.96	R2.22
Fuel levy difference: Petrol	R0.00	R0.00	R0.08	R0.24	R0.35	R0.29	R0.35	R0.37	R0.34	R0.41
Fuel levy difference: Diesel	R0.00	R0.00	R0.10	R0.23	R0.35	R0.29	R0.35	R0.38	R0.33	R0.39

The fund was as productive in 2004 as it was in 2003. The levy on fuel in 2005 had to increase by R0.08 for petrol and R0.10 for diesel and up to R0.41 for petrol and R0.39 for diesel in 2012 in order to preserve its productivity. The fuel levy component must therefore account for over 20% of the fuel price. In future, it will clearly be required, in order to maintain its productivity, that the fuel levy should be increased proportionally more each year, which is only a temporary solution because of improved fuel efficiency and the introduction of electric vehicles to the market.

3.5 Discussion and conclusion

The funding of roads is a complex subject. Roads support economic development and satisfy most of the government's social and development objectives. A clear case to fund roads and ensure a sufficient and reliable revenue source exists if it supports economic development. The question is therefore not whether to fund roads or not, but rather how much funding should be allocated to roads and how to secure revenue from road users.

The literature gives the impression that South Africa does not have a specific, structured and extensive road policy yet. The magnitude of funding required for the road sector is relatively unknown, the amounts stated or projects proposed by the road industry role players are not necessarily economically justified and the share of costs that road users should pay for funding South Africa's road infrastructure is unknown. Current policy documents extensively advocate for the user-pay principle, but this principle in terms of price setting for public infrastructure has a specific meaning, or rather purpose, and does not guarantee that sufficient levels of funding is achieved. It is rather difficult to determine whether road users currently pay too much or less than what is required of them, but it is known that the current price of South Africa's fuel levy, which is ultimately paid by the road users, is not sporadically too high or low compared to international countries given South Africa's large road infrastructure network.

Furthermore, current policy documents do not regulate road tariffs and although there is a move to establish an economic transport regulator, it will not necessarily look at road taxation. This seems to be based more on a fiscal decision to collect revenue for the national fiscus and that economically efficient road taxes based on the user-pay principle are not taken into consideration. These policy documents also do not quantitatively show the actual requirement for funding.

The chapter illustrated that there are various funding sources of different magnitude in South Africa's road funding framework and that not only the fuel levy is important but other taxes as well. Accordingly, South Africa collects quite a lot from road users through actual road use and from owning a vehicle, but this is less than what is invested in the road sector each year. A lot of funding seems to be diverted for the purpose of administration and regulation in the road sector and as such only about 40% of the revenue collected gets invested in actual road infrastructure. Compared to select developed countries in terms of how much revenue South Africa generates and spends on road infrastructure as a percentage of its GDP, the country is definitely not below the norm. The problem may be structural as South Africa have a big road network and a very small vehicle fleet, where too many roads were built and historically road funding was not done economically. However, it seems that the national government is actively allocating (spending) more on road infrastructure each year compared to provincial and municipal governments that are not increasing road infrastructure spending at a stable rate from their revenue account but rather at a marginal rate due to the prioritisation of other expenditure programmes.

South Africa requires a comprehensive, detailed policy based on independent and verifiable research that indicates how much road users should pay to maintain the infrastructure that is important for economic development. It must be acknowledged that roads compete with other infrastructure and social activities and that total cost will not always be covered given South Africa's large road infrastructure and small user base. Thus, hard decisions will have to be taken. An economic regulator is indeed required to set prices at the correct level and to win the confidence of the public, which is not the case in the current setting. In order to improve South Africa's road funding policy, data and performance measures are required. The assessment of current road cost recovery methods is also required, investigating their effectiveness and the impact of future technologies on their revenue-generating potential. It is important to strive for fair and efficient road user charges that adheres to the user-pay principle, whose meaning is not clearly defined and whose calculation is non-existent. The framework should not be oblivious of new road cost recovery methods that are made possible through innovation in technology and that may possibly replace current revenue sources such as DBRUC through location-aware technologies that may be more suited to adapt the user-pay principle. It may be time for tariffs to be differentiated based on external cost that shows the requirement for congestion pricing to be implemented in South Africa.

The chapter showed that the fuel levy, even from its inception, was under pressure to secure adequate funding for road infrastructure. As such, the levy have been increased numerous times over the past century to keep up with road construction, maintenance and upgrade demands. Many plans were put in place to secure this revenue source, but solutions were only temporal and new plans had to be devised. As a result, the fuel levy was supplemented by numerous other revenue sources that are levied on road use. The purpose of the fuel levy has also changed over time from being a revenue source solely for roads to where it now can be spent on any development requirement as determined by government.

The fuel levy and other road cost recovery methods are mandated to source revenue from a relatively small user base for an extensive road network that is starting to deteriorate. Road network sections from across South Africa have become the responsibility of various spheres of government. There is no single road authority ensuring that all road infrastructure gets the same attention. Direct road pricing has also only been implemented on a small section of the road network mainly in the northern provinces of South Africa.

Through a budget analysis for the period, 2010 to 2014, the magnitude and levels of funding from all government departments across all three spheres of government and road-related SOEs and the distribution, allocation and expenditure of these funds were assessed. All of this information was then consolidated into one comprehensive record for analysis. The analysis illustrated that there are various funding sources of different magnitude in South Africa's road funding framework and that not only the fuel levy is important but other taxes as well.

At present, the South African road-funding framework is able to secure a sizeable amount of funding from road users through its road cost recovery methods that are based on actual use of the road network and vehicle ownership. The fuel levy, however, through national government, still contribute the biggest proportion of this funding. Through annual adjustments, the road cost recovery methods' revenue potential is growing significantly, i.e. more than the vehicle fleet, and is adjusted to a level above inflation. Speaking on the distribution of these funds collected there seems to be numerous beneficiaries - each with different mandates. These mandates are not solely based on road construction and include administration and regulatory functions. Only about a third of all funding collected is allocated for the purpose of road construction, but ultimately around 50% is spent on road expenditure whereas the other half is spent on administration and regulatory purposes. It is apparent that the revenue sources through the various road cost recovery methods are not aligned with road expenditure, leaving a shortfall in funding that must be covered by other sectors of the economy.

Through a comparative analysis, the revenue and expenditure of the South African framework was assessed by considering numerous other countries' frameworks in terms of their road expenditure to revenue ratio, their road expenditure to GDP ratio and their road allocation to revenue ratio. South Africa seems to be relatively on par with how much funding is generated, allocated and invested in the road network compared to other countries. However, in terms of the road expenditure to GDP South Africa tend to be on the high end but not below the norm, but this is to be expected of a country still developing and which has an extensive road network coupled with the focus of infrastructure-led growth and job creation.

A productivity analysis was conducted to evaluate South Africa's fuel levy in terms of other countries' fuel levies. The fuel levy and price of fuel appear to be relatively cheap compared with other countries. In addition, the revenue from fuel levies is also impacted by alternative fuels, electric vehicles and vehicles that are more efficient. While the registered vehicle population of South Africa grew 47.2% between 2003 and 2012, vehicle km increased by 38.5% and fuel sales increased by only 21.9%. However, the fuel levy loses its productivity compared to different indexes. This results in less revenue each year per unit of consumption or km per vehicle being generated by the fuel levy. The fuel levy should therefore have been increased more than it has been in recent years to keep up with current trends in road construction. However, that would have had many negative repercussions on road users and on the economy, such as lower revenues to spend on others and higher prices for goods and services. Moreover, South Africa is not alone in experiencing an increasingly unproductive levy on fuel. That said, other countries are also experiencing economic trends in transportation. However, many countries are actively participating in projects to identify feasible alternatives to the revenue source.

The following chapter continues to evaluate the need for DBRUC by assessing to what extent the current South African road cost recovery methods will be able to secure funding for roads in the future given the emergence of disruptive transport technologies and societal trends.

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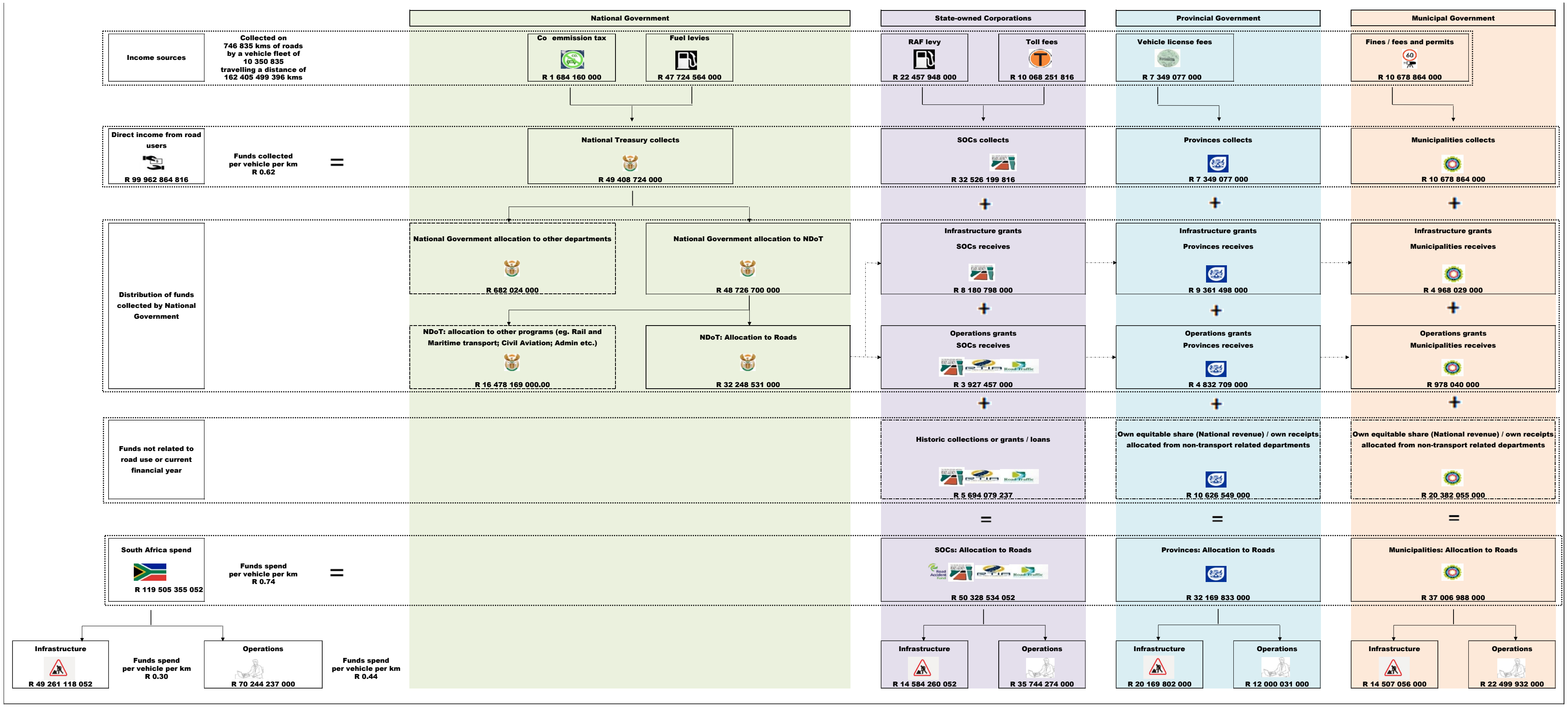
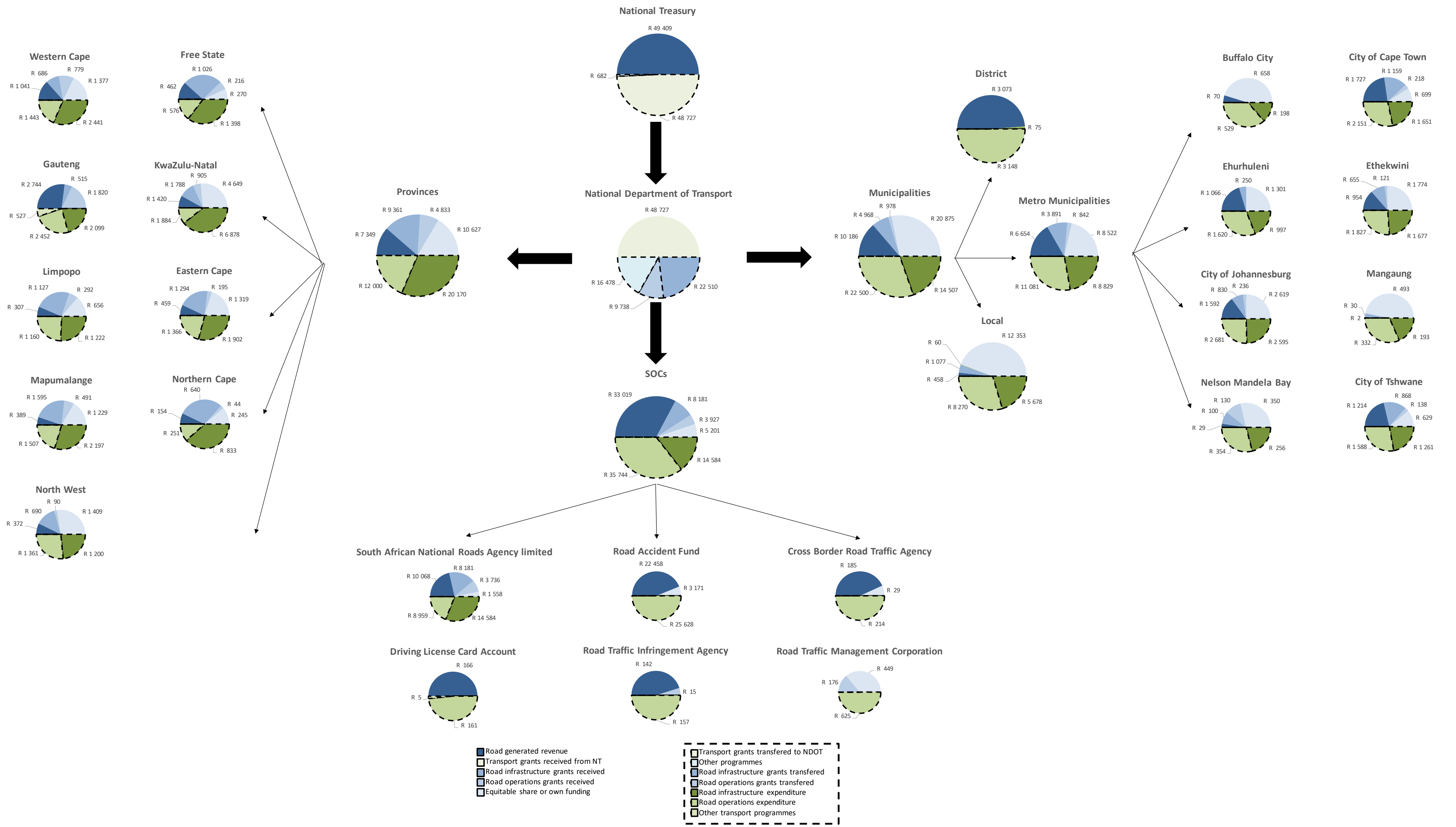
Appendix 3.A | The collection, allocation, expenditure and distribution of road funding in South Africa on a macro-level (2014)



Appendix 3.B | The collection, allocation, expenditure and distribution of road funding in South Africa on a micro-level (2014)



Chapter 4. Estimating the impact of disruptive transport technologies and societal trends on road cost recovery methods[1]

Chapter 1 identified DBRUC as a road cost recovery method, which could possibly be implemented within the current South African road-funding framework to secure funding from road users to meet the road sector's infrastructure expenditure requirements. Chapter 2 then presented a comprehensive literature review discussing the existing knowledge and research on this system and identifying areas or challenges that require further research. Chapter 3 showed that although there is a discrepancy between road generated revenue and road expenditure, the South African road-funding framework are able to collect a sizeable amount of income for road infrastructure provision through its various road cost recovery methods. Chapter 4 aims to address research question 2, which continues to evaluate the need for DBRUC by assessing to what extent the current South African road cost recovery methods will be able to secure funding for roads in the future given the emergence of disruptive transport technologies and societal trends.

The chapter starts by introducing the topic of estimating the impact of disruptive transport technologies and societal trends on road cost recovery methods while explaining its relevance to the study, stating the aim and objectives and outlining the main points of the research. Thereafter a brief review of the impacts and implications of disruptive transport technologies from an international perspective reflecting on its impact on road revenue forecasting, travel behaviour, municipal budgets and transport operator's revenue is provided. It continues by providing a description of the research methodology employed to address the chapter's aim which includes a time series (ARIMA) forecast and scenario analysis, outlining the objective of each method, describing the method design and limitation. This is followed by presenting the research results firstly from forecasting the revenue of South Africa's road cost recovery methods through a time series (ARIMA) analysis giving an account of fuel-based, vehicle-based and user-based road cost recovery methods' potential revenue by the year 2050. This is done by collecting historic revenue amounts of all road cost recovery methods and forecasting the possible revenue to be collected per road cost recovery method. Secondly from estimating the potential revenue impact of disruptive transport technologies and societal trends on South

[1] Sections of this chapter are contained in an article already published in a peer-reviewed conference proceeding (Van Rensburg & Krygsman, 2019).

Africa's road cost recovery methods through a scenario analysis where the effect of eight technological and societal transport changes which include vehicle fuel efficiency improvement, biofuel penetration, electric vehicle penetration, decrease in vehicle km travelled, adoption of greener vehicle technologies, vehicle parts usage efficiency improvement, decrease in vehicle ownership and lack of user compliance is investigated. This is done by reflecting on documented international technological and societal impacts on road cost recovery and subjecting the forecasted road cost recovery method revenue to such a scenario in the South African context. The chapter concludes with a discussion on how technological advancements must not just be seen as affecting the road cost recovery methods negatively but rather how the government can use emerging technologies to its advantage as a way to implement a user-pay principle policy for the road sector.

4.1 Introduction

Innovative technologies change the way the world works in two ways (Hacklin, Raurich & Marxt, 2004). Firstly, they are disruptive as they introduce a new creative product or way of delivering the product that rapidly makes the old product redundant. This will eventually change the current setting. An example of this is, the advancement from powered aircraft to commercial (jet-powered) aviation that made intercontinental passenger steam liners less desirable and led to them being used less frequently. Secondly, innovative technologies introduce incremental changes by providing more value to the customer over time with the same product or service through innovation or improvement. Industry accordingly adopts the latest innovation to standardise a product or service in the short to medium term. An example of this is the installation of Wi-Fi hotspots in shopping malls and city centres.

There is growing concern, and to some extent excitement, that innovative technological changes could have a profound effect on the transport sector (Manyika, Chui, Bughin, Dobbs, Bisson & Marrs, 2013). This outcome is believed to change the way travellers commute in the future. What is worrisome from a governmental perspective is the effect this may have on road revenues collected from road users to aid in the funding of a country's road network. Revenue from South African road users and vehicle owners surpassed R100 billion per annum in 2014 and fluctuates based on the vehicle fleet and magnitude of road use (Department of Logistics, 2017). Although this income is substantial, it is already less than what is currently invested in the road transport sector each year, meaning that the shortfall must be covered by other sectors of the economy. However, as public infrastructure is subject to economic evaluation and not financial evaluation, a certain amount of funding shortfall can be expected.

It is, however, unknown to what extent disruptive transport technologies may affect the country's future ability to recover the road user cost in a fair and effective manner to secure funding and financing for government to address its development goals through investment, especially in the road sector.

Therefore, this chapter aims to continue to evaluate the need for DBRUC by assessing to what extent the current South African road cost recovery methods will be able to secure funding for roads in the future given the emergence of disruptive transport technologies and societal trends. This will be done by i) forecasting the revenue of South Africa's road cost recovery methods through a time series (ARIMA) forecast, and ii) estimating the potential revenue impact of disruptive transport technologies and societal trends on South Africa's road cost recovery methods through a scenario analysis.

4.2 Literature review

The literature review provides an overview of the impacts and implications of disruptive transport technologies on transport activities' revenue generation from an international perspective. In addition, the potential benefits these technologies may conversely have for the economy are considered.

4.2.1 International impacts and implications of disruptive transport technologies

Although the discussion on the impacts and implications of disruptive technologies on road revenues is ongoing, academics and industry experts are of the view that one of the expected results of new technology is greater funding uncertainty (Wachs & Moore, 2018). This was made apparent in a discussion session during the Transportation Research Board conference on surface transportation finance in California where Martin Wachs of RAND stated that the prediction window to accurately estimate future road revenues was getting smaller, falling from twenty years into the future in the 1980s to where it can now only predict confidently three years into the future. Adrian Moore of the Reason Foundation concurred with this statement at this discussion session and added that ridership demand and societal views of how commuters need to travel in the future will make building predictive funding models more difficult.

The development of the shared mobility landscape, which includes e-hailing services such as Uber and Lyft and vehicle-sharing models such as Zipcar in the USA could result in a change in commuter travel behaviour, reducing the user base of the conventional road charging methods (Clewlow & Mishra, 2017). It was found through a survey of over 4000 respondents undertaken in seven major metropolitan areas in the USA that 9% of e-haling users sold their vehicles. Furthermore, depending on the public transport service under review, e-hailing services could have a substituting or complementary effect. An average reduction of 6% in public transport services was accordingly noted.

Similarly, San Francisco in the USA already experienced a 10% reduction in parking revenue over the past two years, while Portland experienced a 10%-25% reduction in total transport revenues in municipal budgets (Larco, 2018). Larco (2018) noted that telecommunication may substitute travel, leading to less parking space and resulting in greater urbanisation in the place of unused parking lots. An Australian study in turn suggested that disruptive transport technologies may result in the reduction of the revenue collected by governments from among others the fuel levy, parking fees and congestion charges. This may be due to the increased usage of e-hailing services and EVs that use less fuel and hence pay less road user charges (Institute for Sensible Transport, 2016). Other transport modes are also affected by the advent of disruptive transport technologies (Mandle, 2018). Airport revenue could be affected as the airport industry generates revenue through its aeronautical operations and non-aeronautical services such as parking, rental cars and ground transportation. If this latter revenue stream declines, airports would have to increase landing charges whereby airlines would have to implement higher airline rates and charges to its customers, leading to a potential loss of air service demand.

Conversely, disruptive technologies are not all harmful. Just as it may have an adverse effect on an economic sector or company activity from one perspective, it may have benefits from another. One such advantage could be the increase in productivity and efficiency of resources, which lowers cost. Less air travel due to increased cost would mean fewer high-altitude CO_2 and other fossil fuel emissions. Less fuel sold could similarly lead to fewer emissions at ground level and consequently better air quality and health gains (Moran & Baker, 2016).

4.3 Research methodology

In order to evaluating the requirement for DBRUC by assessing to what extent the current South African road cost recovery methods will be able to secure funding for roads in the future given the emergence of disruptive transportation technologies, a time series (ARIMA) forecast and scenario analysis were performed. This section briefly provides an overview of each technique employed, where after these techniques are discussed in terms of its objectives, the method employed as well as the limitations of the method.

4.3.1 Time series forecast (ARIMA)

The income from the different components of tax income increase gradually over time. Any attempt to forecast this series using regression or multiple regression will be hampered by the presence of autocorrelation. ARIMA models are therefore considered to forecast the individual road cost recovery methods revenue.

4.3.1.1 Objective of method

The time series (ARIMA) forecast intents to forecast the revenue of South Africa's road cost recovery methods. This method set out to determine the revenue-generating potential of the road cost recovery methods to the year 2050. ARIMA models address autocorrelation. Most time series can be made "stationary" by differencing. A time series is stationary if its statistical properties are all constant over time. Therefore, series with trends or seasonality are not stationary. One way to address this issue, in the absence of seasonality, is to model the differences of the series.

The process followed to fit an ARIMA model to the levy time series data is as follows (Makridakis, Wheelwright & Hyndman, 1998):

1. Plot the data and identify unusual observations.
2. Determine the first differences of the non-stationary data.
3. Examine the autocorrelation function (ACF) and partial autocorrelation function (PACF) of the differenced data, to decide whether lagged values of the time series data (autoregressive model) or the error terms should be added to the model.
4. The chosen model is an ARIMA(1,1,0) model and can be described as follows:

The ARIMA (1,1,0) is a differenced first-order autoregressive model. In this case, the errors after the first difference are autocorrelated, and the problem is fixed by adding one lag of the differenced dependent variable to the prediction equation, therefore by regressing the first difference of Y on itself lagged by one period. This would yield the following prediction equation (Duke, reference):

$$\hat{Y}t - Yt\text{-}1 = \mu + \phi 1(Yt\text{-}1 - Yt\text{-}2)$$

which can be rearranged to

$$\hat{Y}t = \mu + Yt\text{-}1 + \phi 1 (Yt\text{-}1 - Yt\text{-}2),$$

where $\hat{Y}t$ is the predicted value for the series in time t, μ is a constant, Yt-1 and Yt-2 are the actual values of the time series in period t-1 and t-2 respectively, and $\phi 1$ the coefficient of the lagged difference. The result is a first-order autoregressive model with one order of nonseasonal differencing and a constant term, or an ARIMA (1,1,0) model.

5. The residuals from the chosen model are examined by plotting the ACF of the residuals, and doing the Ljung-Box test of the residuals, which test the hypothesis whether the residual autocorrelations as a set are significantly different from zero. The model should be reformulated if that is the case (Makridakis *et al.*, 1998)
6. Once all conditions are satisfied the model is used to forecast the series.

4.3.1.2 Description of method

Using time series (ARIMA) forecasting, South Africa's road cost recovery methods' future revenue was forecast up to the year 2050. Road cost recovery method's revenue data was sourced from numerous government departments and road-related SOEs' financial reports from the year 1988 to 2022. These departments and entities are tasked with collecting fees and charges from road users through the 12 road cost recovery methods as set out in South Africa's road funding framework.

As identified in Chapter 3, these road cost recovery methods include, the Fuel levy, the RAF Fuel Levy, the Custom and Excise levy, the Demand Side Management Levy, the IP Marker Levy, the

Petroleum Products levy (pipeline), license fees, CO_2 emissions, tyre levy, fines, fees and permits, and toll fees both from SANRAL and its concessions.

The government collects revenue from vehicle owners and road users by using 12 road cost recovery methods (presented in Table 4.1), with direct road user charges and mainly the fuel levy adhering to adequacy, equity, efficiency and simplicity principles (Archer, 2018). The amount of revenue that can be generated by a road user charge or levy is dependent on a cost component whose value is determined at government level and a measuring unit component, which is determined by the design of the road cost recovery method. The amount of cost paid by a road user is determined by multiplying these two components in relation to how much of the measuring unit is used.

In general, the South African road cost recovery methods can be grouped into three categories. The first category is fuel-based recovery, which consists of six methods (i.e. the Fuel Levy, The Road Accident Fund Levy, the Custom and Excise Levy, the Demand Side Management Levy, the IP Marker Levy and the Petroleum Products Levy) solely incorporated into the price of fossil fuels charged at a set rate per unit used and paid at the pump. This category accounts for 70% of all road-generated revenues collected through the various cost recovery methods. The second category is vehicle-based consisting of three recovery methods (i.e. License Fees, CO_2 emissions and the Tyre Levy) that take effect on an annual basis, when a vehicle is purchased or when new tyres are bought. This category accounts for 9% of all road-generated revenue. The final category is user-based, which entails a further three recovery methods (i.e. Fines, Fees and permits, Toll Fees and Toll Fee Concessions) and is only paid when the road user makes use of certain road infrastructure under various conditions or is penalised due to inappropriate driver behaviour. This accounts for a further 21% of all road-generated revenue.

The cost component is only affected and adjusted annually to reflect fiscal policy, such as the requirement for revenue or inflationary increases. In turn, the measuring unit component (quantity used) may be affected by technological advancements and social activities (trends). The measuring unit component may have a close relation or may be subjected to these technological advancements. These technological and societal trends include improved vehicle fuel efficiency, the introduction of biofuels and electric vehicles, the reduction in vehicle km travelled, the use of greener vehicle technologies and vehicle parts that last longer, the decrease in vehicle ownership and the lack of user payment compliance (see Table 4.1).

Table 4.1 | South Africa's road cost recovery methods and affecting trends

				Components that determine individual road cost recovery methods' revenue		Trends impacting cost and measuring unit components		
Category % of road-generated revenue	**Method % of road-generated revenue**	**Road cost recovery category**	**Road cost recovery method**	**Cost component**	**Measuring unit component**	**Technological trends**	**Social trends**	**Political decisions**
70%	**47%**	**Fuel-based**	**Fuel Levy**	Charge (tax) amount (R)	Fuel sales (#)	Vehicle fuel efficiency, Biofuels and Electric vehicles	Distance travelled, vehicle ownership	Charge increase or decrease
	22%		**Road Accident Fund Levy**	Charge (tax) amount (R)	Fuel sales (#)			Charge increase or decrease
	1%		**Custom and Excise Levy**	Charge (tax) amount (R)	Fuel sales (#)			Charge increase or decrease
	<1%		**Demand Side Management Levy**	Charge (tax) amount (R)	Fuel sales (#)			Charge increase or decrease
	<1%		**IP Marker Levy**	Charge (tax) amount (R)	Fuel sales (#)			Charge increase or decrease
	<1%		**Petroleum Products Levy (Pipeline)**	Charge (tax) amount (R)	Fuel sales (#)			Charge increase or decrease
9%	**7%**	**Vehicle-based**	**License fees**	Fee amount (R)	Vehicles (#)		Vehicle ownership and user compliance	Charge increase or decrease
	2%		**CO_2 emissions**	Fee (tax) amount (R)	CO_2 emissions of new vehicles above threshold (#)	Greener vehicle technologies	Vehicle ownership	Charge increase or decrease
	<1%		**Tyre Levy**	Charge (tax) amount (R)	Weight of new tyres sold (#)	Usage efficiency	Vehicle ownership	Charge increase or decrease increase
21%	**11%**	**User-based**	**Fines, fees and permits**	Fee and Charge amount (R)	Vehicles (#)		Vehicle ownership and user compliance	Charge increase or decrease
	4%		**Toll fees**	Fee amount (R)	Vehicles using toll roads (#)		Vehicle ownership and distance travelled	Charge increase or decrease increase
	6%		**Toll fees concessions**	Fee amount (R)	Vehicles using toll roads (#)		Vehicle ownership and distance travelled	Charge increase or decrease increase

4.3.1.3 Method limitation

A limitation of using the time series (ARIMA) forecasting is that it is not always accurate. This approach assumes that the events that influence the performance variable prior to the forecast is still in place and disregard any variable that currently or in the future may have an impact on the revenue-generating potential. The longer the forecast, the greater the possibility for error, because the lapse of time will inevitably introduce new variables that influence revenue generated. This was evident during the Covid-19 pandemic of 2020-2021 where hard lockdowns restricted the use of road infrastructure that greatly impacted the collection capability of the fuel levy.

4.3.2 Scenario analysis

Scenario analysis is a process of analysing possible future events by considering alternative possible outcomes. Thus, scenario analysis, which is one of the main forms of projection, does not try to show an exact picture of the future. Instead, it presents several alternative future developments. Scenario analysis is commonly used to estimate changes to a portfolio's value in response to an unfavourable event and may be used to examine a theoretical worst-case scenario.

4.3.2.1 Objective of method

The objective of the scenario analysis method was to assess what impact technological and societal trends may have on the revenue-generating potential of the South African road cost recovery methods. Through this method, the aim was further to identify the technological or societal trend that will have the biggest impact on road cost recovery revenue and which road cost recovery method is most in danger given the emergence of disruptive transportation innovations. This will give an indication of the methods that are most at risk in the future to become economically inefficient and might require a review of their applicability in the South African road-funding framework at a certain time in the future.

4.3.2.2 Description of method

Following the revenue forecast, the assessment of the impact that the various trends may hold, were undertaken and assumed the emergence of these trends since the year 2020. These trends were projected through hypothetical scenario analysis on the forecasted revenues of the road cost recovery methods calculated to show the potential revenue loss that each trend might hold for each projected year. This entailed, in its simplest form, calculating the average revenue per measuring unit and multiplying that value by the number of measuring units lost or affected due to the trend.

The method set out to identify the major technological and societal trends for which some form of data was available to measure the impacts on the road cost recovery methods' revenue-generating potential. For the technological trend, which includes vehicle fuel efficiency, the introduction of biofuels and electric vehicles, the implementation of greener vehicle technologies, and the usage efficiency of vehicle parts, was identified as having the most profound effect on revenue-generating ability. For the societal trend, this included the reduction of the distance travelled by road users, the impact of decreased vehicle ownership and the lack of user compliance.

4.3.2.3 Method limitation

A limitation of this method lied in the accuracy of the potential impact that each technological and societal trend may hold in the South African context. As research on the impacts of technological and societal trends is in its infancy in South Africa, data was rarely available. For this reason, data from international studies and reports was used for analysis. Although this data is not theoretically comparable to the South African context, it will provide an indication of what may happen in the future.

4.4 Research results

The results section firstly presents the findings from performing the time series (ARIMA) forecast where the revenue of the South African road cost recovery methods was forecast. Here the forecasted revenue of i) the fuel-based road cost recovery methods which include the fuel levy, the road accident fund, the custom and excise levy, the demand side management levy, the IP marker levy and the petroleum products levy, ii) the vehicle-based road cost recovery methods which include licence fees, CO_2 emissions and the tyre levy and iii) user-based road cost recovery methods which include fines/fees and permits, and toll fees are discussed. Secondly, it presents the findings from performing the scenario analysis where the potential revenue impact of disruptive transport technologies and societal trends on South Africa's road cost recovery methods was calculated. Eight trends that might have an impact on future road cost recovery method's revenue which include i) vehicle fuel efficiency improvement, ii) bio-fuel penetration, iii) electric vehicle penetration, iv) decrease in vehicle km travelled, v) the adoption of greener vehicle technologies, vi) vehicle parts usage efficiency improvement, vii) decrease in vehicle ownership and viii) lack of user compliance are discussed.

4.4.1 Forecasting the revenue of South Africa's road cost recovery methods

Using time series (ARIMA) forecasting, South Africa's road cost recovery methods' future revenue was forecast up to the year 2050. Data was sourced from numerous government departments and road-related SOEs' financial reports from the year 1988 to 2022 (see Table 4.2). These departments and entities are tasked with collecting fees and charges from road users through the 12 road cost recovery methods as set out in South Africa's road funding framework.

Table 4.2 | South Africa's road cost recovery methods' revenue forecast

'000 000		Actual		Projected		
Category	**Road cost recovery method**	**2010**	**2020**	**2030**	**2040**	**2050**
Fuel-based	**Fuel Levy**	R34 696	R75 460	R105 293	R130 075	R154 858
	Road Accident Fund Levy	R15 570	R42 331	R60 576	R75 151	R89 726
	Custom and Excise Levy	R865	R818	R959	R1 060	R1 161
	Demand Side Management Levy	R1 145	R876	R811	R679	R547
	IP Marker Levy	R2	R12	R20	R29	R37
	Petroleum Products Levy (Pipeline)	R32	R67	R108	R146	R184
Vehicle-based	**License fees**	R5 057	R10 855	R15 581	R20 312	R25 043
	CO_2 emissions	R625	R1 405	R2 168	R2 931	R3 694
	Tyre Levy	R0	R708	R1 512	R2 560	R3 608
User-based	**Fines, fees and permits**	R9 011	R11 945	R14 868	R17 792	R20 716
	Toll fees	R2 073	R4 176	R6 276	R8 375	R10 475
	Toll fees concessions	R3 987	R6 281	R8 606	R10 930	R13 254
	Total road-generated revenue	R73 067	R154 938	R216 784	R270 047	R323 310

(Sources: Department of Energy, 2013; SAPIA, 2014; Statistics South Africa, 2014; National Treasury, 2014b, 2014a, 2014c, 2015; Road Accident Fund, 2014; International Transport Forum, 2015; Bakwena, 2016; SANRAL, 2016; Trans African Concession, 2016; N3TC, 2016; Road Traffic Management Corporation, 2016)

Following the revenue forecast, the assessment of the impact that the various trends may hold, as mentioned in section three, were undertaken and assumed the emergence of these trends since the year 2020. These trends were projected through hypothetical scenario analysis on the forecasted revenues of the road cost recovery methods calculated in Table 4.2 to show the potential revenue loss that each trend may hold for each projected year. This entailed, in its simplest form, calculating the average revenue per measuring unit and multiplying this value by the number of measuring units lost or affected due to the trend.

4.4.2 Estimating the potential revenue impact of disruptive transport technologies and societal trends on South Africa's road cost recovery methods

4.4.2.1 Vehicle fuel efficiency improvement

As a starting point, it was found that in terms of vehicle fuel efficiency, according to the European Environment Agency, passenger vehicles' fuel efficiency (laboratory-based) increased by an average of 1% per annum between the 1990 and 2011 due to technological advancements (European Environment Agency, 2015). This trend was confirmed by the United States Energy Information Administration (2015). It must be noted that a large proportion of vehicles sold in South Africa are not sourced from or sold in Europe or the USA and thus using European and American data can only provide a partial indication of what might transpire in South Africa. Applying the efficiency improvement to the revenue forecast showed revenue loss if assumed that all new vehicles bought in South Africa from 2020 onward follow this efficiency trend (see Table 4.3).

Table 4.3 | Revenue loss due to vehicle fuel efficiency improvement

'000 000		Actual	Projection with trends			
Category	**Road cost recovery method**	**2010**	**2020**	**2030**	**2040**	**2050**
Fuel-based	**Fuel Levy**	R0	R327	R2 567	R2 733	R2 820
	Road Accident Fund Levy	R0	R183	R1 477	R1 832	R2 188
	Custom and Excise Levy	R0	R4	R23	R26	R28
	Demand Side Management Levy	R0	R4	R20	R17	R13
	IP Marker Levy	R0	R0	R1	R1	R1
	Petroleum Products Levy (Pipeline)	R0	R0	R3	R4	R5
	Total revenue loss	R0	R518	R4 091	R4 612	R5 055
	Total revenue % loss	0%	-0.33%	-1.89%	-1.71%	-1.56%

4.4.2.2 Biofuel penetration

It is envisaged that the share in bio-fuel sales in relation to total fossil fuel sales will be 2% from 2020 onward (Reuters, 2013). This shows a revenue loss of less than 2% for the near future for all fuel-based road cost recovery methods (see Table 4.4).

Table 4.4 | Revenue loss due to biofuel penetration

‘000 000		Actual	Projection with trends			
Category	**Road cost recovery method**	**2010**	**2020**	**2030**	**2040**	**2050**
Fuel-based	**Fuel Levy**	R0	R1 509	R2 106	R2 602	R3 097
	Road Accident Fund Levy	R0	R847	R1 212	R1 503	R1 795
	Custom and Excise Levy	R0	R16	R19	R21	R23
	Demand Side Management Levy	R0	R18	R16	R14	R11
	IP Marker Levy	R0	R0	R0	R1	R1
	Petroleum Products Levy (Pipeline)	R0	R1	R2	R3	R4
	Total revenue loss	R0	R2 391	R3 355	R4 143	R4 930
	Total revenue % loss	0%	-1.54%	-1.55%	-1.53%	-1.52%

4.4.2.3 Electric vehicle penetration

Hybrid vehicle technologies can increase fuel efficiency (laboratory-based) up to 35% (National Research Council, 2015). For example, stop-start systems reduce idle waste, renewable braking systems capable of reusing and recovering small amounts of braking power and larger electric motor and battery power generator systems reduce fuel consumption. These technological advancements have and will continue to decrease vehicles’ fuel consumption significantly to the point where all vehicle propulsion systems are completely electric and not reliant on any fossil fuels. According to a report by the University of Cape Town (Dane, 2013), it is envisaged that the growth in electric and hybrid vehicles will be 1 500 vehicles per annum when the market is penetrated. Although this statement is over-enthusiastic, in reality by 2017 South Africa had only sold 375 electric vehicles (EV) (BusinessTech, 2018). Nonetheless, a forecast was done to test the effect of this envisaged amount showing <0.1% reduction in fuel-based generated revenue with an electric vehicle population of 22 500 by 2050. However, this trend still holds the biggest threat for the future as new electric vehicle brands are emerging rapidly (Randall, 2017) and will make up a large percentage of new vehicles bought when all accompanying infrastructure, such as public charging stations, is in place in the country.

Table 4.5 | Revenue loss due to EV penetration

‘000 000		Actual	Projection with trends			
Category	**Road cost recovery method**	**2010**	**2020**	**2030**	**2040**	**2050**
Fuel-based	**Fuel Levy**	R0	R58	R176	R218	R260
	Road Accident Fund Levy	R0	R32	R102	R126	R150
	Custom and Excise Levy	R0	R1	R2	R2	R2
	Demand Side Management Levy	R0	R1	R1	R1	R1
	IP Marker Levy	R0	<R1	<R1	<R1	<R1
	Petroleum Products Levy (Pipeline)	R0	<R1	<R1	<R1	<R1
	Total revenue loss	R0	R92	281	347	413
	Total revenue % loss	0%	-0.0006%	-0.0013%	-0.0013%	-0.0013%

4.4.2.4 Decrease in vehicle kilometres travelled

The total vehicle km travelled by the registered population of vehicles increased by 38.5% between 2003 and 2012 at an average annual rate of 3.7% (Van Rensburg & Krygsman, 2015). Over the same period, South Africa's total registered vehicle population grew by 47.2% at an average annual growth rate of 4.4%. Although this data is required to be updated, it showed that within this decade on average vehicle km travelled per vehicle in South Africa decreased at a rate of 110 km per year. This trend when projected also shows marginal revenue losses (see Table 4.6).

Table 4.6 I Revenue loss due to decreased distance travelled

'000 000		Actual	Projection with trends			
Category	**Road cost recovery method**	**2010**	**2020**	**2030**	**2040**	**2050**
Fuel-based	Fuel Levy	R0	R624	R724	R894	R1 064
	Road Accident Fund Levy	R0	R350	R416	R516	R617
	Custom and Excise Levy	R0	R7	R7	R7	R8
	Demand Side Management Levy	R0	R7	R6	R5	R4
	IP Marker Levy	R0	R0	R0	R0	R0
	Petroleum Products Levy (Pipeline)	R0	R1	R1	R1	R1
User-based	Toll fees	R0	R35	R43	R44	R43
	Toll fees concessions	R0	R52	R59	R57	R54
	Total revenue loss	R0	R1 075	R1 255	R1 524	R1 791
	Total revenue % loss	0%	-0.69%	-0.58%	-0.56%	-0.55%

4.4.2.5 Adoption of greener vehicle technologies

Effective driving of EVs instead of conventional fossil fuel vehicles may not reduce CO_2 emissions on a global scale. Indeed, charging electric vehicles on electricity grids that depend highly on fossil fuel (coal) sources may boost emissions of carbon dioxide. In Germany, a negligible EV emissions difference of 4.9% from fossil fuels showed a possible reduction in CO_2 emissions of only 8.7% (Richard, 2017). As international standards are set with regard to curbing global warming and initiatives such as the independently produced renewable energy programme are introduced, the revenue loss of this trend might decrease, but would be marginal at best for the coming years, as it will only be required to be implemented in new vehicles (see Table 4.7).

Table 4.7 | Revenue loss due to greener vehicle technologies

'000 000		Actual	Projection with trends			
Category	**Road cost recovery method**	**2010**	**2020**	**2030**	**2040**	**2050**
Vehicle-based	**CO_2 emissions**	R0	R126	R194	R262	R331
	Total revenue loss	R0	R126	R194	R262	R331
	Total revenue % loss	0%	-0.08%	-0.09%	-0.10%	-0.10%

4.4.2.6 Vehicle parts usage efficiency improvement

A tyre study conducted by Nussbaum Transportation of Hudson showed a 20% improvement in tyre life and a 3% fuel economy gain (compared to a control group) in recent years using balancing compounds in tyres at all wheel positions (Park, 2016). Tyre grip gets worse as they wear. On average, front tyres on a front-wheel-drive vehicle last only about 30 000 km and the rear tyres about double that. This is an inefficient cost recovery method as a replacement of tyres can take several years and as such has almost no real effect on road-generated revenue (see Table 4.8).

Table 4.8 | Revenue loss due to vehicle parts usage efficiency

'000 000		Actual	Projection with trends			
Category	**Road cost recovery method**	**2010**	**2020**	**2030**	**2040**	**2050**
Vehicle-based	**Tyre Levy**	R0	R142	R303	R512	R722
	Total revenue loss	R0	R142	R303	R512	R722
	Total revenue % loss	0%	-0.09%	-0.14%	-0.19%	-0.22%

4.4.2.7 Decrease in vehicle ownership

The worlds evolving relationship with cars is mainly driven by e-hailers. This had a significant impact on drivers, cities and the vehicle manufacturing industry as a whole. A recent Lyft report stated that the company has delivered 375.5 million passengers in 2017, with 250.000 passenger vehicles specifically removed in the USA alone as a result of e-hailing services (Hallgren, 2018). This could possibly occur in South Africa with the increased usage of Uber, but with the majority of vehicle owners being middle-income to high-income workers, with congestion at almost critical levels, they would rather make use of the comfort of their own vehicle than sitting in traffic in an e-hailing vehicle. Entertaining an envisaged decreased vehicle ownership of 250 000 vehicles per annum effectively shows a large impact on road-generated revenues as the years progress (see Table 4.9).

Table 4.9 | Revenue loss due to decreased vehicle ownership

'000 000		Actual	Projection with trends			
Category	**Road cost recovery method**	**2010**	**2020**	**2030**	**2040**	**2050**
Fuel-based	**Fuel Levy**	R0	R1 877	R6 108	R7 546	R 984
	Road Accident Fund Levy	R0	R1 053	R3 514	R4 360	R5 205
	Custom and Excise Levy	R0	R20	R56	R62	R67
	Demand Side Management Levy	R0	R22	R47	R39	R32
	IP Marker Levy	R0	R0	R1	R2	R2
	Petroleum Products Levy (Pipeline)	R0	R2	R6	R8	R11
Vehicle-based	**License fees**	R0	R1 388	R4 352	R7 795	R11 525
	CO_2 emissions	R0	R1 428	R2 086	R2 815	R3 548
	Tyre Levy	R0	R15	R26	R38	R46
User-based	**Fines, fees and permits**	R0	R255	R260	R263	R265
	Toll fees	R0	R89	R110	R124	R134
	Toll fees concessions	R0	R134	R150	R161	R169
	Total revenue loss	R0	R9 099	R23 154	R33 822	R45 060
	Total revenue % loss	0%	-5.87%	-10.68%	-12.52%	-13.94%

4.4.2.8 Lack of user compliance

A major concern is that it is estimated that some four-million vehicles on South Africa's roads are unregistered (Venter, 2008). It must be noted that it is uncertain whether this amount increased or decreased over the past decade as no updated estimates could be found. Furthermore, before the Administrative Adjudication of Road Traffic Offences System (AARTO) was piloted in 2008 in Johannesburg, the City had issued 655 719 fines, which had only a 10.25% payment rate (Magubane, 2016). Consequently, more than 1.3bn (more than 71%) of the more than 1.8bn invoices issued with the advent of the e-toll system were unpaid (Peyper, 2017). Although traffic fines and toll system payments are not directly comparable, the above aims only to give an indication of the level of user compliance in South Africa. User compliance is a major issue in South Africa due to corruption and sometimes-political preferences and ideologies. Therefore, there is essentially a breakdown in trust between the user and the government. Many South Africans pay transport-based accounts such as vehicle license fees and traffic fines regularly, so it is safer to say that around 50% of all road users are non-compliant. This shows a lack of user compliance as the third-most concerning factor that may have an impact on road revenues (-4.79% by 2050) after a decrease in vehicle ownership and improved vehicle fuel efficiency as shown above (-13.94% and -1.56% respectively by 2050) (see Table 4.10).

Table 4.10 | Revenue loss due to lack of user compliance

'000 000		Actual	Projection with trends			
Category	**Road cost recovery method**	**2010**	**2020**	**2030**	**2040**	**2050**
Vehicle-based	**License fees**	R0	R3 700	R4 352	R4 796	R5 122
User-based	**Fines, fees and permits**	R0	R5 972	R7 434	R8 896	R10 358
	Total revenue loss	R0	R9 673	R11 786	R13 692	R15 480
	Total revenue % loss	0%	-6.2%	-5.44%	-5.07%	-4.79%

4.4.2.9 Total potential revenue impact

Assuming all the listed trends and the associated impacts were to take effect from the year 2020, it is evident that most of the impact is quite small in the short term to what one would imagine. It must also be kept in mind that this possible decrease in road-generated revenue must be added to a possible, if not guaranteed, shortfall in the normal budgeting process for the transport sector. It might be safe to say that given no profound disruption occurs, such as oil price shocks given geopolitics that might drive technological advances, mass electric vehicle adoption up to 2050 and the continued lockdown regulation due to the Covid-19 pandemic, technological and societal trends will only have an incremental impact on road-generated revenues every five years and will not be as disruptive as initially thought (see Table 4.11).

Table 4.11 | South Africa's road cost recovery methods' total revenue loss due to disruptive technologies and societal trends

'000 000		Actual	Projection with trends			
Category	**Road cost recovery method**	**2010**	**2020**	**2030**	**2040**	**2050**
Fuel-based	**Fuel Levy**	R0	R4 395	R11 682	R13 993	R16 225
	Road Accident Fund Levy	R0	R2 465	R6 721	R8 338	R9 955
	Custom and Excise Levy	R0	R48	R106	R118	R129
	Demand Side Management Levy	R0	R51	R90	R75	R61
	IP Marker Levy	R0	R1	R2	R3	R4
	Petroleum Products Levy (Pipeline)	R0	R4	R12	R16	R20
	Total revenue loss	R0	R6 963	R18 613	R22 543	R26 394
	Total revenue % loss	0%	-4.49%	-8.59%	-8.35%	-8.16%
Vehicle-based	**License fees**	R0	R5 089	R8 704	R12 591	R16 647
	CO_2 emissions	R0	R1 554	R2 280	R3 078	R3 878
	Tyre Levy	R0	R157	R329	R550	R768
	Total revenue loss	R0	R6 799	R11 313	R16 219	R21 293
	Total revenue % loss	0%	-4.39%	-5.22%	-6.01%	-6.59%
User-based	**Fines, fees and permits**	R0	R6 227	R7 694	R9 159	R10 623
	Toll fees	R0	R124	R153	R167	R177
	Toll fees concessions	R0	R186	R209	R218	R224
	Total revenue loss	R0	R6 536	R8 056	R9 544	R11 023
	Total revenue % loss	0%	-4.22%	-3.72%	-3.53%	-3.41%
	Total road-generated revenue loss due to technological and societal trends	R0	R20 299	R37 982	R48 306	R58 710
	Total road-generated revenue % loss due to technological and societal trends	0%	-13.10%	-17.52%	-17.89%	-18.16%

4.5 Discussion and conclusion

Innovations in technology can disrupt normal operating procedures or incrementally provide more value to the users of the technology. However, these changes could have both positive and negative effects for the road sector whereby it could change commuters' travel behaviour to a more sustainable form of transport. However, of greater concern is the effect this could have on revenue generated through road cost recovery methods.

The current chapter discussed the potential impact that disruptive transport technologies may have on road-generated revenues in South Africa. It was argued that the current models used by the government to tax road users for road use and vehicle ownership are not immune to technological and societal trends. This chapter commenced by presenting on a strategic level in section two a quantitative overview of the investigation made into the possible impacts of disruptive transport technologies on road revenues from an international perspective, mainly from the USA perspective. It was found that it already had to some extent an impact on road funding revenue forecasting, travel behaviour, municipal budgets and transport operators' revenue.

Focussing on the South African road-funding framework, the study identified several technological and societal trends that may have an impact on future road-generated revenues. Forecasting these revenues, through a time series (ARIMA) analysis and using scenario analysis, showed that although new technology will have an impact on future road-generated revenues, it is more incremental in the short to medium terms than disruptive as previously envisaged. However, the shortfall of 18% in 2050 will become the responsibility of road users who will have to pay the shortfall through higher fees and charges or, alternatively, the aid will come from other sectors of the economy. Luckily, the impact of disruptive and social trends will not be so bad for South Africa if it is compared to countries that have a dedicated road fund. Thus, the revenue that is lost will be captured through other taxes or charges due to road users having more disposable income to spend on other expenses. The results further show that full-scale adoption of especially EVs and reduced vehicle ownership due to e-hailing services will have a profound effect on road-generated revenues, especially revenues collected through fuel-based cost recovery methods. Future road-generated revenue projections will become inaccurate and will have a detrimental effect on budget planning if sufficient attention is not paid to the possible impact that disruptive transport technologies may have. Government departments and road-related SOEs tasked with collecting fees and charges from road users have to be aware that disruptive technologies are present and that more will emerge in the near future. It must, therefore, ensure that contingency plans for collecting road-generated revenue is in place so as not to become victims of the disruption.

It is recommended that the new emerging technologies should not be seen as barriers that will complicate and reduce the amount of future road-generated revenues, but rather as ways to implement a fair and efficient transport or road funding framework that incorporates the user-pay principle. The user-pay principle's meaning must still be clearly defined and monetary value calculated in the South African context. One such emerging technology that may be beneficial in the African context is the use of location-aware technologies, such as vehicle tracking GPS devices, to charge vehicles based on the distance that they travel. Such a system will be resistant to many technological and some societal trends and can combine many of the existing road cost recovery methods revenue potential through a single road usage fee.

The following chapter evaluates the appropriateness of DBRUC by assessing to what extent the South African road-funding framework reflect fair and efficient road user charges.

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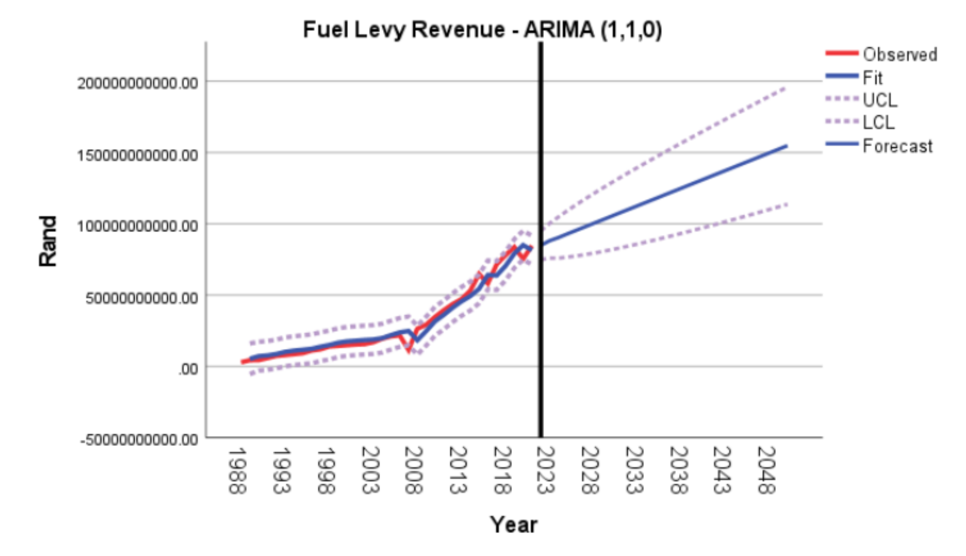
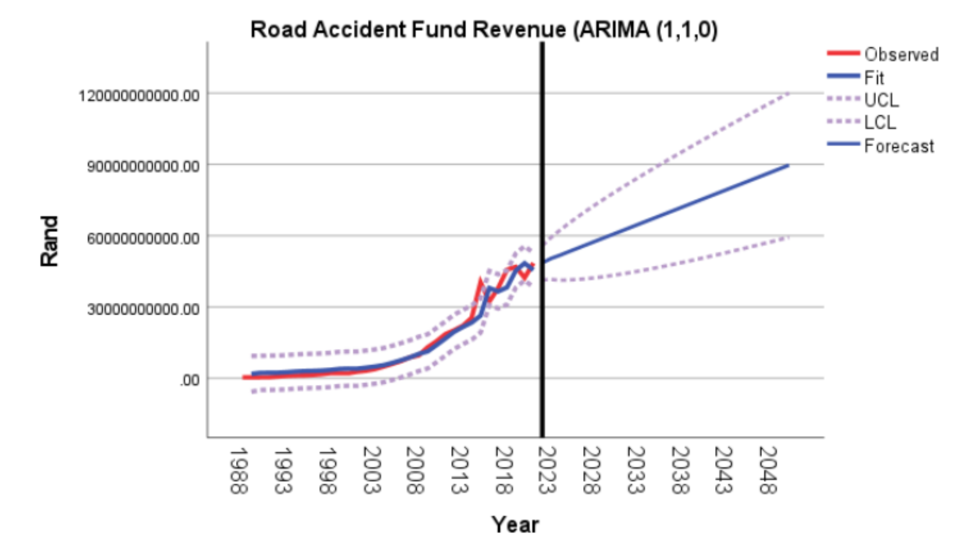
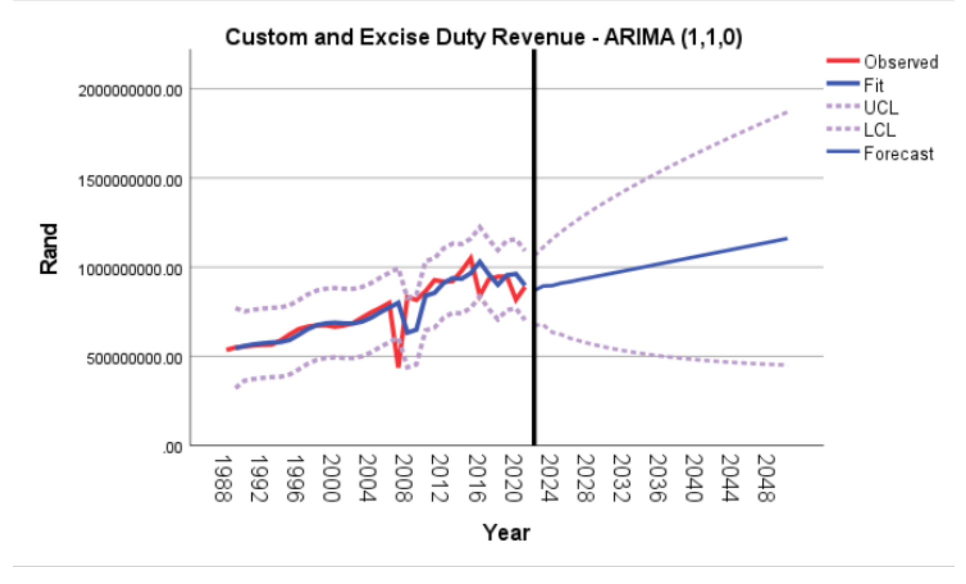
Appendix 4.A | Time series forecast for variables



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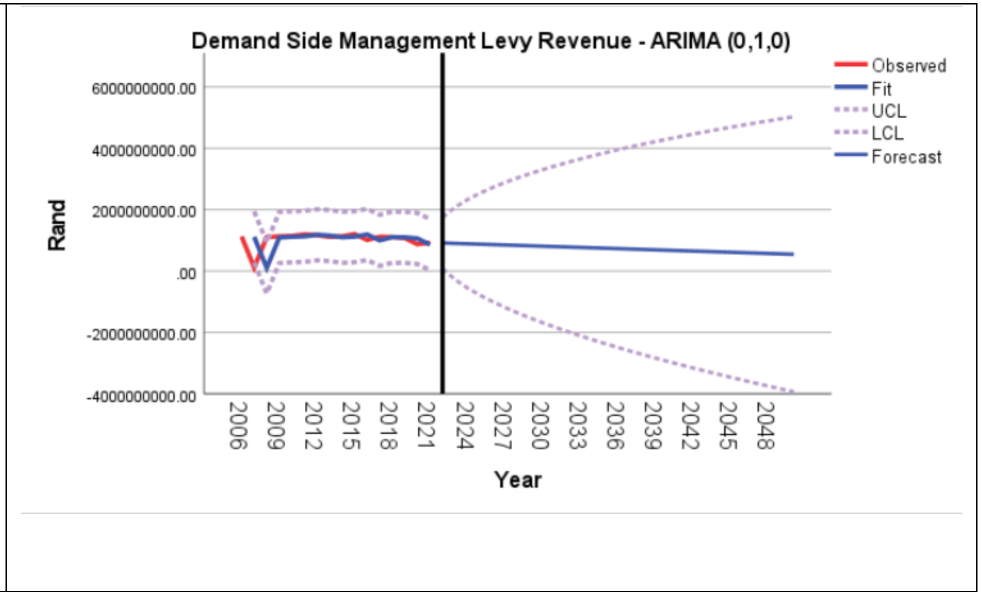
1500000000.00
1000000000.00
500000000.00
.00
Year
1988
1992
1996
2000
2004
2008
2012
2016
2020
2024
2028
2032
2036
2040
2044
2048
Observed
Fit
UCL
LCL
Forecast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4000000000.00
2000000000.00
.00
-2000000000.00
-4000000000.00
Year
2006
2009
2012
2015
2018
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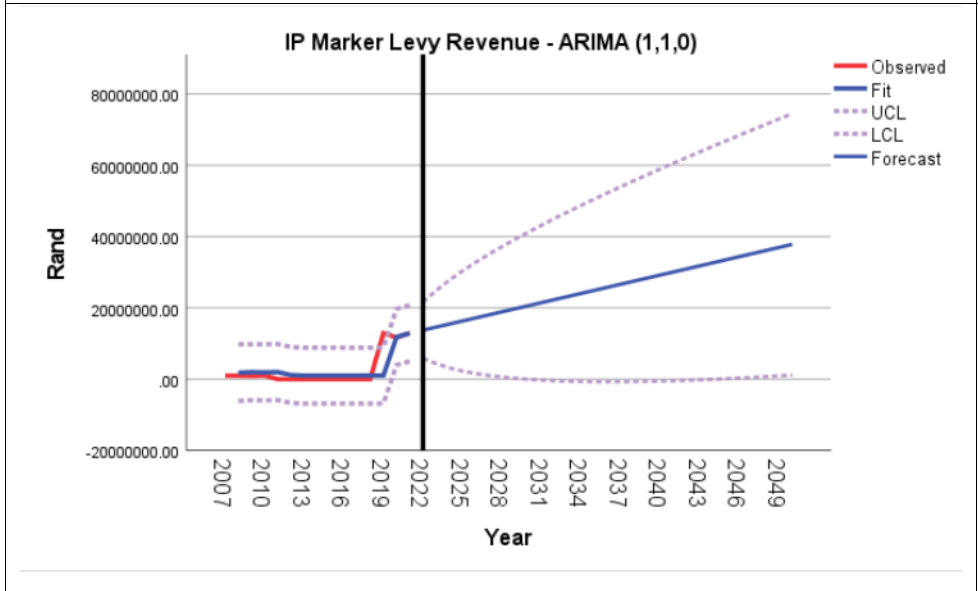
2048
Observed
Fit
UCL
LCL
Forecast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Rand
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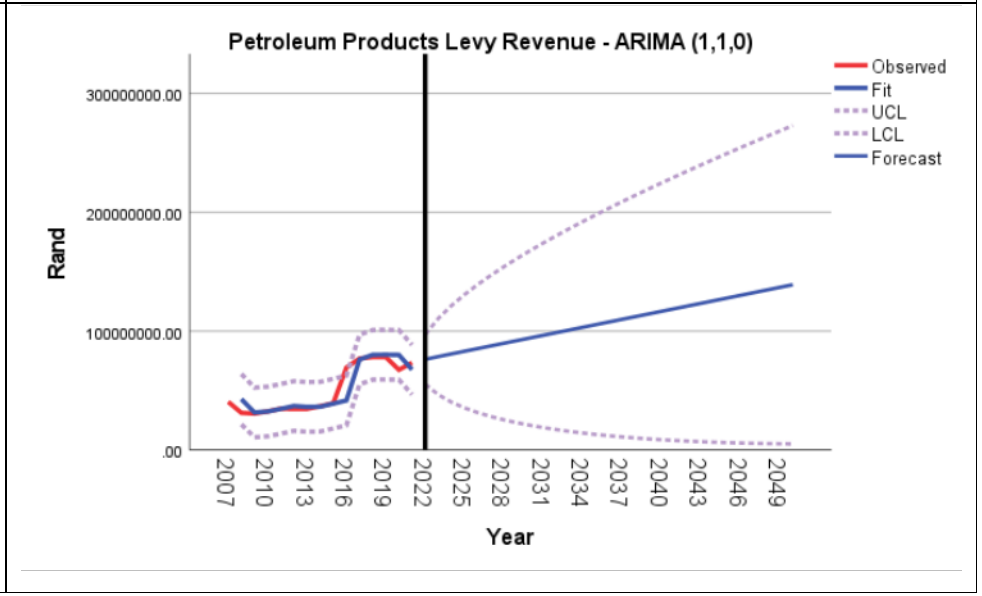
60000000.00
40000000.00
20000000.00
.00
-20000000.00
Year
2007
2010
2013
2016
2019
2022
2025
2028
2031
2034
2037
2040
2043
2046
2049
Observed
Fit
UCL
LCL
Forecast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Rand
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.00
Year
2007
2010
2013
2016
2019
2022
2025
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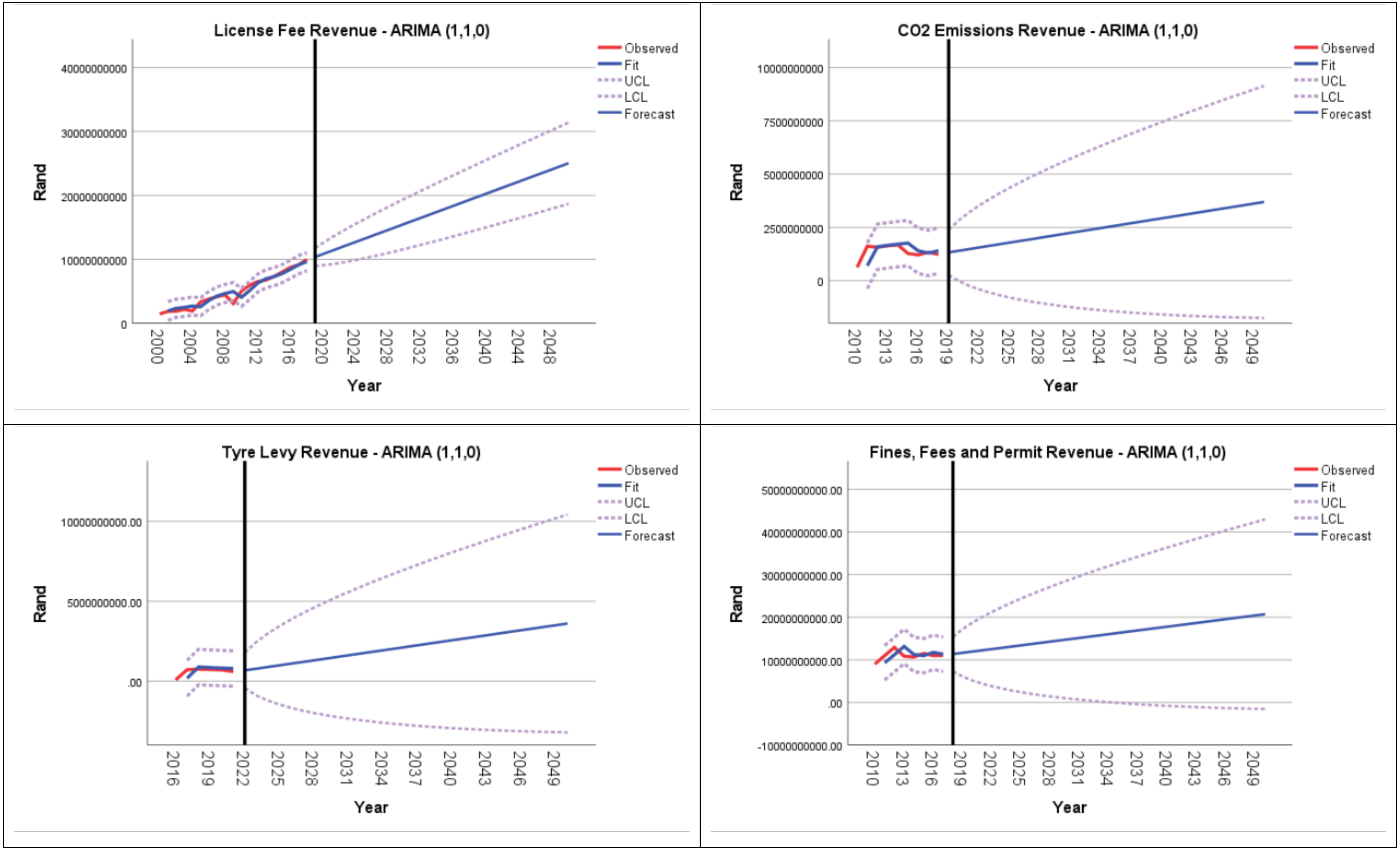
2034
2037
2040
2043
2046
2049
Observed
Fit
UCL
LCL
Forecast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10000000000
0
2000 2004 2008 2012 2016 2020 2024 2028 2032 2036 2040 2044 2048
Year
Observed
Fit
UCL
LCL
Forecast
CO2 Emissions Revenue - ARIMA (1,1,0)
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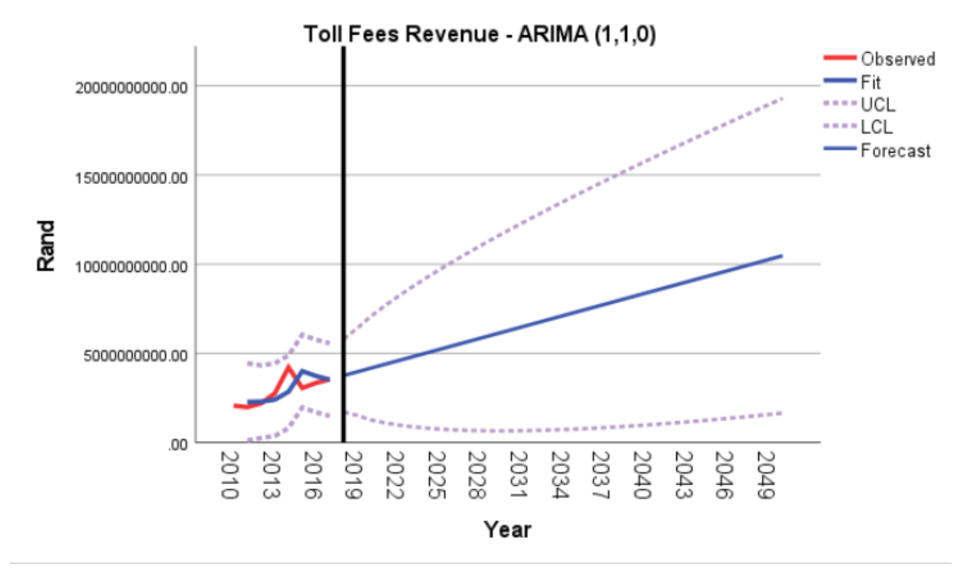
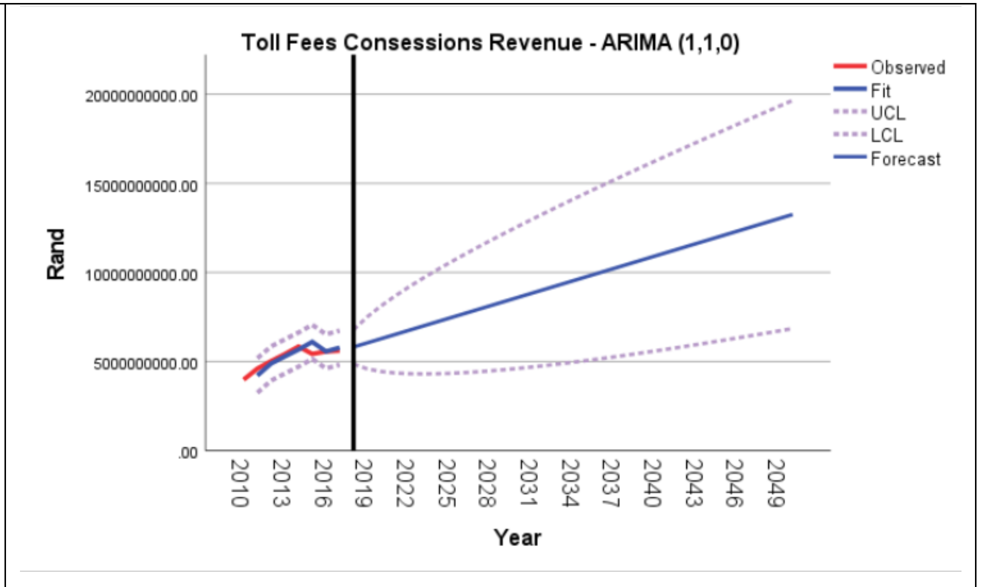
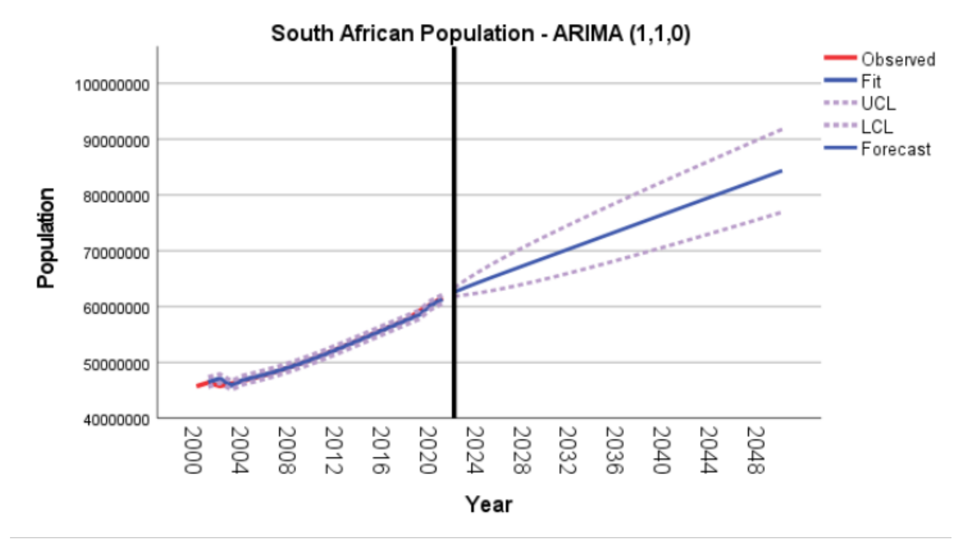
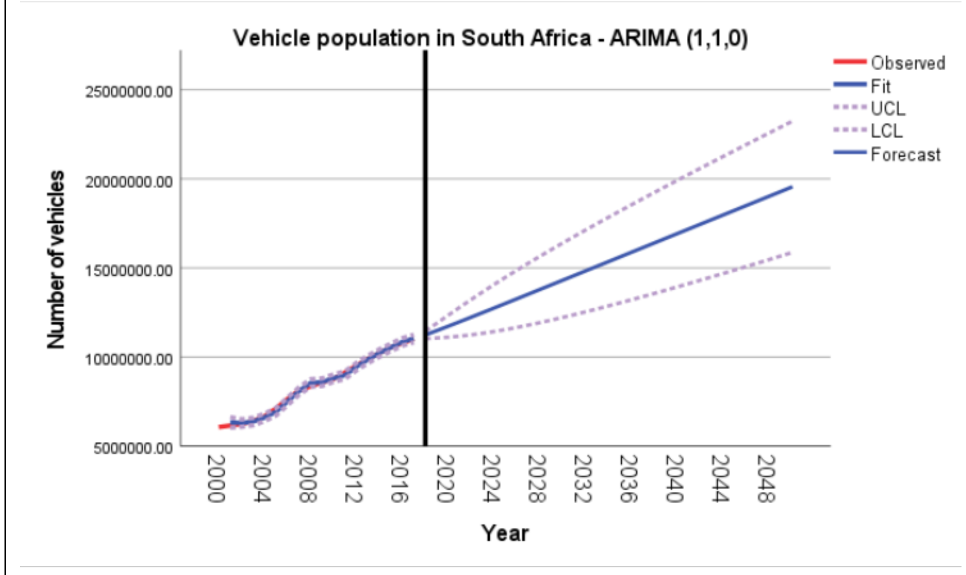
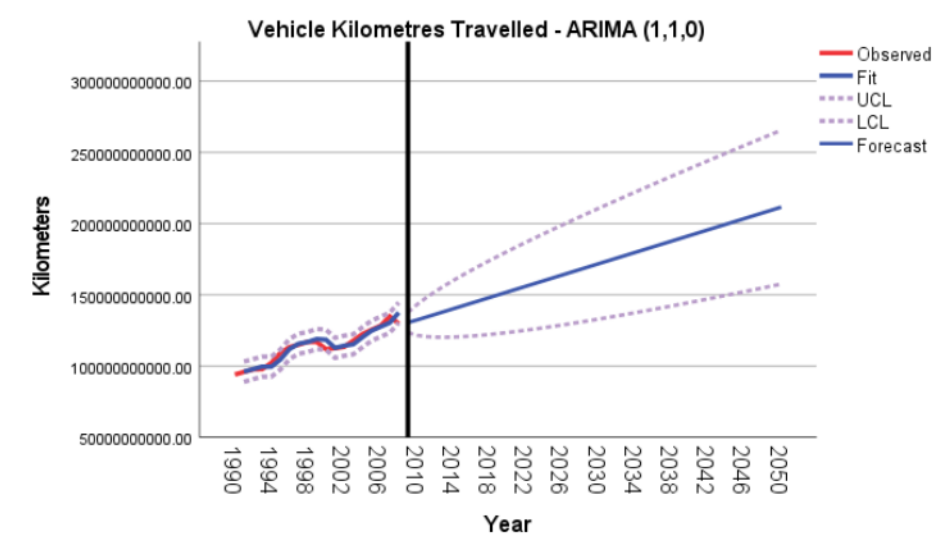
7500000000
5000000000
2500000000
0
2010 2013 2016 2019 2022 2025 2028 2031 2034 2037 2040 2043 2046 2049
Year
Observed
Fit
UCL
LCL
Forecast
Tyre Levy Revenue - ARIMA (1,1,0)
Rand
10000000000.00
5000000000.00
.00
2016 2019 2022 2025 2028 2031 2034 2037 2040 2043 2046 2049
Year
Observed
Fit
UCL
LCL
Forecast
Fines, Fees and Permit Revenue - ARIMA (1,1,0)
Rand
50000000000.00
40000000000.00
30000000000.00
20000000000.00
10000000000.00
.00
-10000000000.00
2010 2013 2016 2019 2022 2025 2028 2031 2034 2037 2040 2043 2046 2049
Year
Observed
Fit
UCL
LCL
Forecast

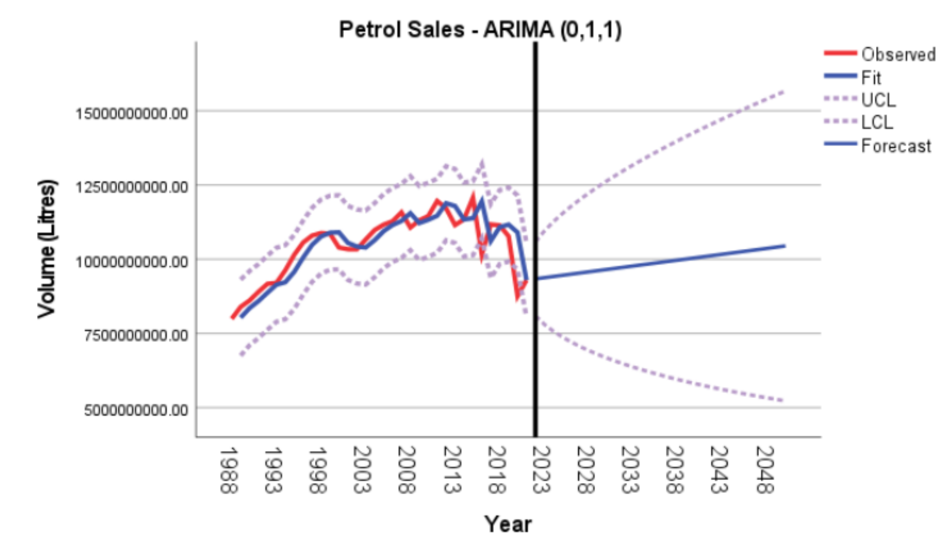

Toll Fees Revenue - ARIMA (1,1,0)
Observed
Fit
UCL
LCL
Forecast
Rand
20000000000.00
15000000000.00
10000000000.00
5000000000.00
.00
2010 2013 2016 2019 2022 2025 2028 2031 2034 2037 2040 2043 2046 2049
Year

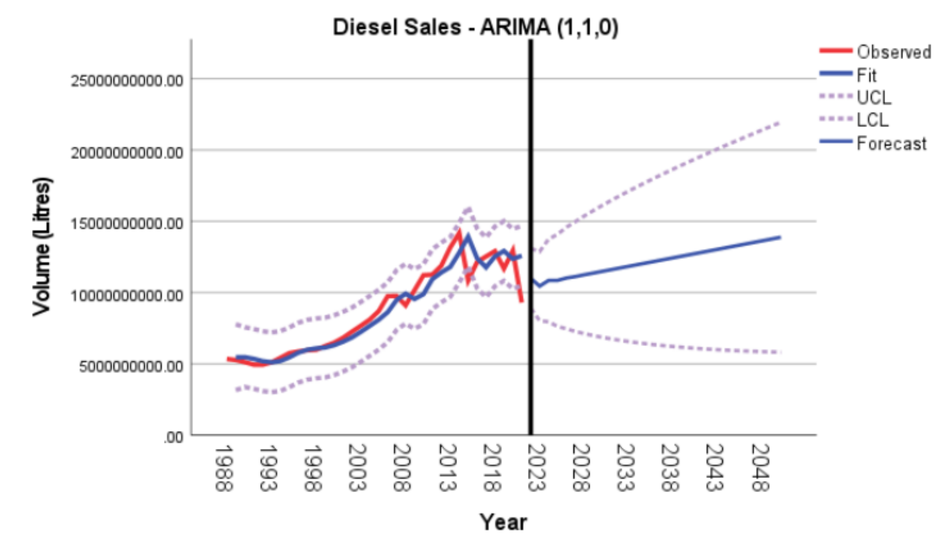

Toll Fees Consessions Revenue - ARIMA (1,1,0)
Observed
Fit
UCL
LCL
Forecast
Rand
20000000000.00
15000000000.00
10000000000.00
5000000000.00
.00
2010 2013 2016 2019 2022 2025 2028 2031 2034 2037 2040 2043 2046 2049
Year


South African Population - ARIMA (1,1,0)
Observed
Fit
UCL
LCL
Forecast
Population
100000000
90000000
80000000
70000000
60000000
50000000
40000000
2000 2004 2008 2012 2016 2020 2024 2028 2032 2036 2040 2044 2048
Year


Vehicle population in South Africa - ARIMA (1,1,0)
Observed
Fit
UCL
LCL
Forecast
Number of vehicles
25000000.00
20000000.00
15000000.00
10000000.00
5000000.00
2000 2004 2008 2012 2016 2020 2024 2028 2032 2036 2040 2044 2048
Year


Vehicle Kilometres Travelled - ARIMA (1,1,0)
Kilometers
300000000000.00
250000000000.00
200000000000.00
150000000000.00
100000000000.00
50000000000.00
1990
1994
1998
2002
2006
2010
2014
2018
2022
2026
2030
2034
2038
2042
2046
2050
Year
Observed
Fit
UCL
LCL
Forecast


Petrol Sales - ARIMA (0,1,1)
Volume (Litres)
15000000000.00
12500000000.00
10000000000.00
7500000000.00
5000000000.00
1988
1993
1998
2003
2008
2013
2018
2023
2028
2033
2038
2043
2048
Year
Observed
Fit
UCL
LCL
Forecast


Diesel Sales - ARIMA (1,1,0)
Volume (Litres)
25000000000.00
20000000000.00
15000000000.00
10000000000.00
5000000000.00
.00
1988
1993
1998
2003
2008
2013
2018
2023
2028
2033
2038
2043
2048
Year
Observed
Fit
UCL
LCL
Forecast

Chapter 5. Deriving fair and efficient road user charges[1]

In Chapter 1 the study aim was formulated to evaluate the need, appropriateness and practicality of DBRUC using GPS-enabled vehicle tracking devices and a short-run MSC-based fare structure as a road cost recovery method in the South African road-funding framework. This was followed by a comprehensive literature review in Chapter 2 to provide a clear understanding of DBRUC and where it fits into the road-funding environment, discussing the existing knowledge and research on this system and identifying areas or challenges that require further research. Chapter 3 showed that the current South African road-funding framework is able to secure funding for roads to a great extent, but that the fuel levy is starting to show signs of decline when expressed per vehicle or km basis. Chapter 4 found that the emergence of disruptive transport technologies and societal trends will have a minor effect on most road cost recovery methods, but that fuel based systems are most at risk in experiencing declining revenues. Chapter 5 aims to address research question 3 which evaluates the appropriateness of DBRUC by assessing to what extent the South African road-funding framework reflect fair and efficient road user charges.

The chapter starts by introducing the topic of deriving fair and efficient road user charges while explaining its relevance to the study, stating the aim and objectives and outlining the main points of the research. Thereafter a literature review is presented to explain the relationship between roads and economic and social development and unpacking the meaning of the user-pay principle. It continues by providing a description of the research methodology employed to address the chapter's aim which includes an impact assessment and the application of the social economic cost responsibility principle and purchasing power parity theory (PPP), outlining the objective of each method, describing the method design and limitation. This is followed by presenting the research results firstly from calculating the impact of the South African road-funding framework on road users through an impact assessment investigating the affordability of fuel in South Africa and the magnitude of transport costs on individual and household budgets. This is done by allocating the income of a hypothetical average South African, an average fuel-based motorist and an average electric-based motorist to expenditure needs with the focus on transportation costs. Secondly from deriving a short-run MSC-based road user charge through firstly applying the social economic cost responsibility principle to derive the

[1] Sections of this chapter are contained in an article already published in a peer-reviewed conference proceeding (Van Rensburg & Krygsman, 2019).

marginal infrastructure cost, marginal congestion cost, marginal accident cost, marginal environmental cost and the total MSC for which road users is responsible and then secondly applying purchasing power parity to derive a variable MSC-based fee structure. This is done by estimating each MSC component in terms of an average charge per vehicle km drawing on cost estimates from the road industry, and then using European MSC estimates and converting this into values for South Africa that differentiates road user charges by vehicle type, area of usage, road type used and travelling conditions. The chapter concludes by recommending a way forward to address the current policy vacuum to regulate and ensure fair and efficient rod user charges.

5.1 Introduction

Road infrastructure and all the transport services that use roads, such as private vehicle owners, public transport operators and goods transporters, improve living standards for the public and aid business development, provide a social service, and generally contribute to a government's developmental goal of supporting its country's economy. Policy makers have always responded positively to this relationship between roads and prosperity and as a result have invested heavily in roads. This was and remains the case in South Africa.

A general theme in government and SOE policy documents and statements seems to indicate the government's and SOEs' preference to adopt the so-called user-pay principle to fund roads. Other than these general statements, no documents elaborate on the principle and what it entails. The popular press, on the contrary, seems to favour a more equitable allocation of the fuel levy, assuming that the fuel levy is sufficient if fully allocated to the road sector. Non-government civil action organisations typically support this viewpoint, often calling for the ring-fencing of the fuel levy for road infrastructure spending. The public is sceptical of government taxes and, if the recent experience with tolls is anything to go by, will be very reluctant to accept a new road tax or any form of toll. Civilian action organisations actively engage in this debate under the banner of fighting tax abuse. The various conflicting groups argue for or against toll roads, ring-fencing the fuel levy, lessening the financial load on motorists and stopping the subsidising of other economic sectors by the road sector. Nearly weekly revelations about state capture, corruption and the squandering of tax revenues increase the unease of people to continue to finance government spending (Visser, 2017). How roads should be funded, i.e. who should pay and how much they should pay, seems to be the main point of contention.

Despite all these conflicting views, there is surprisingly little research in South Africa on road funding. In fact, there have been very little research on road funding since Peter Freeman conducted his seminal work, "The Road Cost Recovery Study", in the 1980s (Freeman, 1982). The limited studies that have been undertaken in South Africa have focussed on how to fund roads (as a non-pure public good) (Mirrilees, 1989; Naude, 1996) and on the issues of how much users should pay and who should fund roads (Brits, 2010; Stander & Pienaar, 2006). What is evident from the very limited number of studies undertaken in South Africa is that i) the fuel levy may not be a viable long-term solution given technological developments, ii) road user charges based on weight distance charges may accurately reflect road users costs, and iii) South Africans may be paying more road use tax than what their share of road use demands.

The general lack of research further pertains to the following:

1. The unavailability of data on the size, composition and growth projections of the South African vehicle fleet;
2. Revenue from road use and expenditure on the road network;
3. Costs caused by road users including maintenance;
4. Social and environmental unit costs;
5. The allocation of costs to road user types;
6. Information on administration of road funding;
7. The value of the road network; and
8. An understanding of road user charging principles.

The road sector, broadly including road users, infrastructure service providers, transport operators, the government and SOEs, seems saturated with distrust, suspicion and with untruths about road funding, specifically about who should pay, how they should pay and the requirement for road funding.

Therefore this chapter aims to evaluate the appropriateness of DBRUC by assessing to what extent the South African road funding framework reflect fair and efficient road user charges. This will be done by i) calculating the impact of the South African road funding framework on road users through an impact assessment, and ii) deriving a short-run MSC-based road user charge through the use of the social economic cost responsibility principle and PPP theory.

5.2 Literature review

The literature review describes the significance of roads for economic and social development and provides an argument that this can only be achieved with sufficient, stable modes of funding based on efficient road user charges. The review continues by discussing what efficient road user charges are by unpacking the user-pay-principle by focussing on MSC pricing.

5.2.1 Roads and economic and social development

The theory that transport, and especially transport infrastructure, is growth-enhancing is a fundamental belief that supports the perspective of an infrastructure-led growth strategy (Docherty & MacKinnon, 2013). Empirical support for this viewpoint is often given by referring to the statistical link between growth in GDP or Gross National Product (GNP) and growth in road traffic (goods and passengers) or road network density. The National Planning Commission of South Africa (2009) even suggests that transport is a pillar for economic development and growth. While there is no doubt economic activities, the transportation network and transportation activities, can support development the question is how exactly this would happen.

Investments in transport, such as roads, public transport networks and intermodal transfer facilities, lower the costs of moving people and goods. This decrease in costs may increase the productivity of companies, organisations and individuals in that more time and money are made available, leading to increased output. Productivity, measured in terms of increased output per unit of investment, is a key element of economic growth. Economic growth, when measured in terms of the expansion of the GDP, may lead to a higher standard of living[2]. Seen from this perspective, transport (infrastructure) investments such as building new roads or upgrading existing roads may improve economic wellbeing by enhancing productivity. Central to this argument, however, is that the cost of the road investment should be less than the savings generated by the new road. This implies, of course, that it is possible to overinvest,

[2] Whether or not the growth resulting from an increase in productivity is equally shared among the citizens is not considered here

specifically when i) too much capacity is provided too soon ii) too expensive road infrastructure is provided or iii) the demand remains too low to support the road infrastructure.

While transport investment, and road investment in particular, may in fact support economic development, there are some important prerequisites for development to occur (Banister & Berechman, 2001). Positive economic externalities should be present. These should include agglomeration and labour market economies and the availability of a well-trained accessibility of the workforce. There are investment factors relating to the accessibility of investment funds, investment scale, location, and network effects (no missing network connections) that should be present. Political factors are conducive to support for economic development. The latter involves finance, funding sources, investment levels, legal, organisational and institutional policies, and procedures.

If these prerequisites are not present, any transport investment to support economic development will be severely hindered and may even have counter-development effects as adequately illustrated by Banister and Berechman (2001) .

The savings that transport infrastructure offers can be assessed by the rate of return generated by the investment in transport. Governments at all levels use public funds to invest in transport projects such as roads. These public funds are the result of collected taxes, including the fuel levy and toll fees. To be worthwhile investments, the roads projects selected should deliver a high rate of return in order to ultimately support the goal of increasing productivity and generating economic growth. Therefore, it follows that transport investments should be sound and should be made in response to a requirement as opposed to being driven by supply.

Measuring the impact of transport infrastructure investments on the economy can be assessed at micro and macro level with various analytical techniques. Roads support economic development by bringing about direct savings. Micro economic techniques capture the direct time and cost savings resulting from transport improvements (such as vehicle operating costs), but not the indirect impact of these savings in the form of reduced production costs and possible benefits from the reorganisation of logistical activities. These benefits are then compared to the costs, including external costs, associated with the investment. If these benefits, termed first-order or primary benefits exceed the costs, the transport (road) investment is worthwhile. While these techniques are widely used, they do not consider the network or general equilibrium impacts of investment in transport on the economy's transport-based sectors or the indirect effects induced by road investment. These network benefits may in fact be dramatic in terms of the growth in total factor productivity. Macro-economic modelling techniques are used to capture these price reductions across the economy and the extension of production from investment in transport infrastructure investments (Lakshmanan, 2011). Two other benefits ascribed to transport infrastructure are spatial agglomeration in larger urban areas and innovation and commercialisation of new knowledge in connected areas. That is, good transport connections create productive and efficient cities that stimulate innovation and economies of scale.

Transport, and more specifically road infrastructure investments, can undeniably contribute to improved accessibility (or reduced costs of accessibility), which is key to creating an improved standard of living for citizens by giving them access to job opportunities and more affordable basic services.

The second caveat relates to funding. If public borrowing finances roads, the impact of debt servicing will be felt by other investments, including education and social services. Given South Africa’s current fiscal position, public borrowing may not be feasible. Funding from the fuel levy, as a partial substitute for a road user charge, may lead to one of two outcomes. Unconstrained spending from a well-stocked fuel fund, especially spending that is not related to actual road use, can lead to inflationary pressure. By contrast, insufficient spending on the network, including on the required maintenance and upkeep, would lead to a rapidly deteriorating road network, increasing transport costs and placing time and financial pressure on businesses and citizens. The costs of poor road management and insufficient road financing are, after all, borne mainly by road users through increased vehicle operating costs.

Shifting road investments from the government to the private sector, including public-private partnerships and toll road concessions, may be useful to secure much-required funds. Although these initiatives are becoming more popular globally, they are associated with political inertia, an aversion from road users and enterprise regulation voids with regard to setting road use charges that hamper their rollout and permanent use. Yet, they do offer the possibility of cutting project implementation time significantly and securing funding for much required projects.

Road infrastructure, and indeed all transport infrastructure, can support economic growth and development, but these can only be achieved with sufficient, stable modes of funding based on efficient road user charges. Funds must be spent judiciously and focused on bottlenecks where a deficient road network inhibits growth. Finally, if supporting conditions are not present, investment in road infrastructure to support economic development is not likely to occur.

5.2.2 The user-pay principle

A widely accepted economic principle is that the users of scarce resources should pay the full cost of their consumption of these resources. Adopting this approach, it is argued, will avoid a misallocation of resources, such as spending too much on certain sectors, and the possible distortion of economic processes. In this scenario, the principle would imply that the users of the road, the scarce resource, should pay for using every km of road. This principle is commonly referred to as the user-pay principle, which is an umbrella term. The system of user-pay, however, is neither simple nor is there consensus regarding what users should pay or even what users are already paying.

Three issues problematise this principle. Firstly, the so-called service of roads is not delivered to users in the way that other services (e.g. water and electricity) are. Measuring individual use is therefore difficult, for example because roads are not equally accessible everywhere. Secondly, even non-road users benefit from the presence of roads. In fact, few economic or even social activities do not require roads in some form or other. Thirdly, the identification, measurement and inclusion or exclusion of costs and the allocation of these costs to specific types of users are not trivial exercises.

The different types of road users, from motorcycle and car users to heavy goods vehicle operators, are seldom aware of either the type or the magnitude of all the costs they impose on society and other users of the road infrastructure. Being unaware, or not paying the correct price, has consequences and may lead to a misallocation in the economic sector. The user-pay principle implies that the road user is aware of their road user costs, both private and social, and pays the correct price for road use. Only then, will they make the correct decision(s) in terms of their road use and travel behaviour, leading to a more equitable allocation of resources. Of course, if prices are not set correctly in other sectors (for example, if rail tariffs are too high, the transport infrastructure is not available or there are no public transport options), setting the correct road user tariffs holds very little benefit and may even have undesirable unintended outcomes, such as promoting inequality.

When the prices that are charged to road users are equal to the resource costs, those prices are referred to as efficient prices, as they will result in the economically efficient use of transport resources (Delucchi, 2000). In transport, the term MSC describes this efficient price (Macario, 2010). Marginal refers to the cost of each incremental unit, i.e. each additional unit of traffic. Marginal costs are therefore the costs that can be causally attributed to a specific vehicle at a specific time and a specific place. Marginal user cost differs from average user cost, which refers simply to the total cost of road use of all users divided among all users. Social refers to the cost to society as a whole, as opposed to the cost to the individual. Social therefore includes costs such as congestion, road damage, environmental pollution, accidents and other costs that are traditionally external to the pricing models.

Marginal social cost is equal to marginal private cost (e.g. fuel, travel time and depreciation) plus marginal external cost. Only when MSC equal margin social benefits will an economically efficient price be achieved, leading to an efficient equilibrium.

Note that MSC does not involve users of the road paying sunk costs for past infrastructure expansion (i.e. the capital cost of the road), but only for the damage caused to the pavement of the road, i.e. some maintenance and operational costs. Marginal costs look to the future and not to the past. Only future costs that can be causally linked to road use are considered in marginal cost estimation (Kahn, 1970).

Marginal social cost stands in contrast to the approach where users are paying an amount for road use that bears no relationship to their actual road use. In such a case, the amount can be either above or below the actual resource cost. In the latter case, users are directly or indirectly subsidised to use the resource, while in the former case they are paying more than in the resource case. Both of these outcomes are said to be inefficient. In the case where the user cost exceeds the optimal price, i.e. the MSC, users (notably poorer sections of the community) are discouraged from using the infrastructure, thereby reducing the social benefit provided by roads. A road user cost that is below the optimal resource price, however, will lead to excessive resource consumption, producing higher costs than benefits, and there will be less incentive for individual consumers to decrease the cost they impose on society. An efficient price results in users paying their correct share and adapting their use to an optimal level (where their benefit of use equates to the cost of their use).

While the user-pay principle, as formulated above, seems conceptually sound, MSC holds numerous problems and the system is often considered more theoretical than practical as it presents some serious shortcomings (Rothengatter, 2003). Among these are the fact that its measurement is complex, it ignores equity, it does not consider financing issues (i.e. the requirement to cover costs) and price distortions elsewhere in the economy and its implementation may involve substantial administrative costs. The biggest concern with MSC pricing is probably that it does not guarantee that all costs are covered or that fiscal neutrality is achieved. All of this implies that MSC may not always be justified by the benefits it brings or, in fact, be a realistic option at all.

While some of the shortcomings can be addressed, it must be emphasised that MSC pricing is not a straightforward, practical solution and that it remains for the most part a theoretical approach to pricing policy. In fact, there is no country in the world where the approach is fully implemented. However, this does not mean that the approach should be disregarded. It is generally accepted that MSC pricing should be used as a starting point (i.e. a base price) and that the shortcomings of the system should be accommodated by some optimal departures from the theory (European Commission, 1998).

Implementing the user-pay principle according to theoretical principles is not always an option, as the required conditions are not always met. The measurement of road use is difficult and road use varies enormously between users, making individual-user pricing challenging. The strict implementation of the user-pay principle may therefore not be feasible in South Africa at this stage.

Marginal social cost also does not explicitly consider capacity expansion (the long-term expansion of a network due to increased traffic). When supply exceeds demand, resulting in congestion on roads, MSC pricing will generate excess funds, which can be used to expand the network. Unfortunately, as noted before, short-run MSC fluctuates continuously, which makes implementing the principle difficult.

Vehicle use imposes four major expenses on society, namely i) accident costs, ii) environmental pollution, iii) road damage and iv) congestion (Newbery, 1990). In the absence of road use taxes, society, not the individual road user, generally absorbs these costs. The magnitude and type of cost absorbed by society depends on individuals' classification as road or non-road users. While the benefits of road use, such as fast and affordable access to employment, social and cultural activities are enjoyed by the individual, these external costs of the road provision and use are not always borne by everyone (Korzhenevych, Dehnen, Brocker, Holtkamp, Meier, Gibson, Varma & Cox, 2014). Road users do not consider these external costs in their travel and transport decisions, such as what route to take, when to travel, how many trips to make or even what mode of travel to use. These costs are external to the individual's decision-making framework. Not considering these costs has an impact on society, such as additional (excessive) road capacity demands that lead to further congestion, noise and air pollution, and increased accident risk. Internalising these external costs in road user charges would therefore be fairer and more efficient. Marginal social cost represents such a fair and efficient price.

While the system seems straightforward, the methodology behind the system, the costs categories to include, the calculation, the costs allocation and ultimately the implementation are far from simple. External costs or MSC, as defined here, also differ among various road types (urban roads, rural, intra-urban and other), vehicle technologies (vehicle engine size and vehicle weight) and traffic conditions (free flow, nearing capacity and fully congested). It also differs among urban, sub-urban and rural areas. There is thus not one road user charge, but multiple road user charges differentiated to reflect the different circumstances.

While it is difficult to determine or calculate a road user charge for South Africa, it is possible to illustrate the system using international values and approximations. The values derived in this way should only be seen as an illustration of, firstly, how to determine a road user charge and, secondly, what the important cost components that make up a road user charge are.

5.3 Research methodology

In order to evaluate the appropriateness of DBRUC by assessing to what extent the South African road cost recovery methods adhere to the theoretical foundations of road pricing, an impact assessment was performed and the social economic cost responsibility principle and PPP theory were applied. The research methodology briefly provides an overview of each technique employed, where after these techniques are discussed in terms of its objectives, the method employed as well as the limitations of the method.

5.3.1 Impact assessment

An impact assessment is a structured process for considering the implications, for people and their environment, of proposed actions while there is still an opportunity to modify (or even, if appropriate, abandon) the proposals.

5.3.1.1 Objective of method

The impact assessment intents to calculate the impact of the South African road-funding framework on road users. This is in monetary terms (how much they pay for road use through various fees and charges). This method set out to determine to what extent the fuel levy can be increased as the main road cost recovery method in the South African road-funding framework and how this impact is different between road users driving a conventional internal combustion engine vehicle and a new hybrid or electric vehicle using less or no fuel. It is widely speculated that South Africans are already over taxed and if their cost of transport in turn increases, it leaves road users with less annual income to spend on other expenses.

5.3.1.2 Description of method

The data from a study undertaken by Bloomberg that compared the fuel price, its affordability and the percentage of revenue spent on fuel was compared to the "Income and Expenditure Survey 2010-2011". This survey shows the average revenue and expenditure of road users in South Africa and what their major cost expenditure items are. Furthermore, this survey allowed for empirically determining the magnitude of the effect of transport costs, and the fuel levy in particular, on an individual and household budget. For comparative purposes, the expenditure of the average South African was then compared to that of the average vehicle user and to a hypothetical motorist operating an electric vehicle. For the average South African, 11 expenditure items were listed. These items, as identified in the 2014 Revenue and Expenditure Survey, included housing, food, water, communication, education, electricity, health, fuel, fuel levies and road use charges and fees. The expenditure on transport-based activities was highlighted through an infographic. The same cost items were listed for the average fuel-based vehicle users and the average EV users and, the growth or decline in the transport-based activities was assessed. This was done by assuming both average fuel-based and EV users drove 15 000 km per year and calculating their expenditure in terms of fuel use.

The Bloomberg study further compared the affordability of fuel among 61 countries. This study reports and discusses the South African affordability in this context but only shows the comparison with selected BRICS and OECD countries for simplicity reasons. These countries include Australia, Brazil, Canada, New Zealand, Russia, the UK, USA, India and China. To give an account of the impact on road users operating different vehicle types, only an example of the average South African road user, based on the average South African user operating a fuel-based vehicle and the average South African road user operating an electric vehicle, was used.

5.3.1.3 Method limitation

A limitation of this method was the use of averages. Unfortunately the data did not lend itself for the extraction of a particular South African road user and could only be based on assumptions by the researcher.

5.3.2 Social economic cost responsibility principle and PPP theory

The social economic cost responsibility principle assumes that consumers (for economic efficiency) must carry the full costs of their usage. Purchasing power parities are currency conversion rates that match the purchasing power of distinct currencies by eliminating price-level distinctions between nations. PPPs in their simplest form indicate the price ratio of the same product or service in different countries in national currencies. PPPs are also calculated for groups of products and up to and including GDP for each of the various levels of aggregation. Priced goods and services in the basket is a sample of all those of final expenditure: household consumption, government services, capital formation and GDP-covered net exports. This indicator is evaluated per US dollar in terms of domestic currency.

5.3.2.1 Objective of method

By applying the social economic cost responsibility principle and PPP theory, the study intents to derive a short-run MSC-based road user charge. The method set out to show the dramatic differences in MSC between cars and heavy goods vehicles that travel in and outside of the peak.

5.3.2.2 Description of method

Firstly through the use of the social economic cost responsibility principle the average cost responsibility of road users was calculated by collecting road income and expenditure data as explained in Chapter 3 and averaging this over the vehicle population and the annual km that they drive. Additional cost estimates was sourced to calculate the marginal congestion cost, marginal accident cost, marginal maintenance cost and marginal environmental cost. The total short-run MSC is then compared to the average cost responsibility of the road users. Secondly through the use of PPP this study calculates comparative ranges of MSC for road use in South Africa, and applying it to already-calculated values in the European Union (EU). Note that while these values do not hold any relevance for South Africa, they do show how road user charges are impacted by location, time of day, vehicle characteristics and specifically congestion.

5.3.2.3 Method limitation

A limitation of this methods is that PPP, although giving a representable value compared to other countries, does not take into account the road environment nor the cost and magnitude of the cost incurred. Thus, the calculation is only an indication to show the variations in cost between different vehicle types and roads used.

5.4 Research results

The results section firstly presents the findings from performing the impact assessment where the impact of the South African road-funding framework on road users was calculated. A brief overview of the average cost that road users currently pay and should pay to meet budgetary requirements is provided where after i) the affordability of fuel and ii) the magnitude of transport costs on individual and household budgets are discussed. Secondly, it presents the findings from applying the social economic cost responsibility principle and PPP theory where a short-run MSC-based road user charge was derived. A simple calculation of road user cost based on the historical cost method is firstly provided where after the calculation of i) marginal infrastructure cost, ii) marginal congestion cost iii) marginal accident cost, iv) marginal environmental cost, v) total MSC and vi) variable MSC are discussed.

5.4.1 Calculating the impact of the South African road funding framework on road users

During 2014 and 2015, R100.9 billion was directly collected from the road network and road users through various charges, levies and taxes by all levels of government. This revenue was collected from a vehicle fleet of 10 350 835 travelling a distance of 162 405 499 396 km using the 746 835 km of roads in South Africa. Road user charges resulted in R0.62 of direct revenue collected per vehicle km.

R49.2 billion was spent on road infrastructure (planning and design for road upgrades, maintenance and new construction) by SANRAL, provincial governments and municipal governments. All authorities spent R70.2 billion on road operations and regulation resulting in R119.4 billion being spent on road infrastructure, regulation and operations. This investment was spent on 746 835 km of roads as well as the supporting operational and regulatory agencies in South Africa, used by a vehicle fleet of 10 350 835 travelling a distance of 162 405 499 396 resulting in an investment of R0.74 per vehicle km.

The fuel levy remains the main revenue source acquired from road users that may be used to support road construction and maintenance. It is also a significant component of the direct road-generated revenue (47%) and currently the only nationally levied road use tax that charges users, more or less, in proportion to their amount of road use. To satisfy the theoretical principles of user-pay, it seems that the fuel levy is currently the only tax available to serve as a road user charge. The question remains, however, as to what extent the fuel levy can be increased, if required or whether the current fuel levy represent an appropriate user-pay charge.

5.4.1.1 Affordability of fuel

Bloomberg (Randal, McIntyre & Diamond, 2016) ranked 61 countries by three economic measures to compare the affordability of fuel or, as the publication put it, to determine “who feels the most pain at the pump”. The comparison included countries from Africa, Asia, Europe, North and South America and the Middle East. South Africa was ranked with selected BRICS and OECD nations in this chapter to simplify the figures.

In 2014, the average price of a litre of fuel in South Africa was R13.41. South Africa ranked 16th cheapest of the 61 countries compared and ranked relatively low among the other BRICS and OECD nations (Figure 5.1).

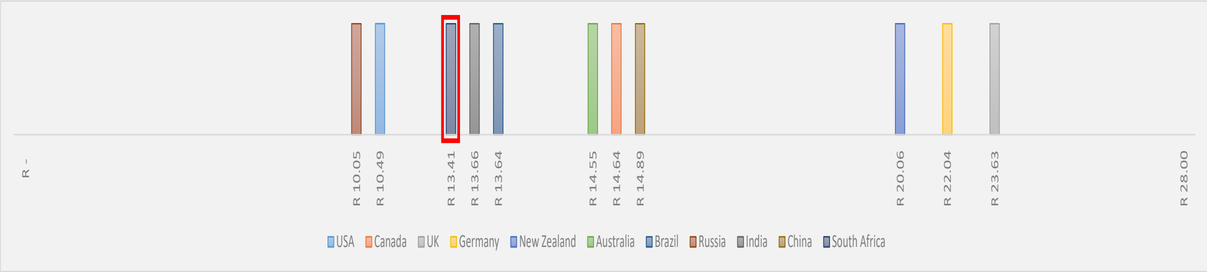


Figure 5.1 I Average fuel price per litre of fuel sold comparison
(Source: Randal, McIntyre and Diamond, 2016)

Affordability is measured as a commodity's cost relative to the amount that the purchaser is able to pay. Using data from the 2014 Revenue and Expenditure Survey (Statistics South Africa, 2011), the average daily revenue in South Africa was R192.64. It would therefore have taken 6.96% of a day's revenue to afford a litre of fuel. This placed the country 53rd, out of 61 countries, in terms of affordability with only India of the BRICS and OECD nations having less affordable fuel (see Figure 5.2).

Figure 5.2 I Affordability of fuel per litre comparison
(Source: Randal, McIntyre and Diamond, 2016)

South Africans face a lot of "pain at the pump", as expressed by the Bloomberg analysis, which is further exacerbated by how much fuel the country consumes. In no other country do people spend more of their salary filling up. The average driver in South Africa uses 216.6 litres of fuel per year, which consumes 4.13% of the typical salary. South Africa is ranked 61st out of all the countries, as well as the worst among the BRICS and OECD nations (Figure 5.3). This may in fact also be an indication of the inefficiency of land use patterns in South Africa with sprawling cities and low-revenue residents located on the outskirts of towns and cities. Such spatial patterns lead to a mismatch between housing and employment, resulting in long commutes mostly with private vehicles.

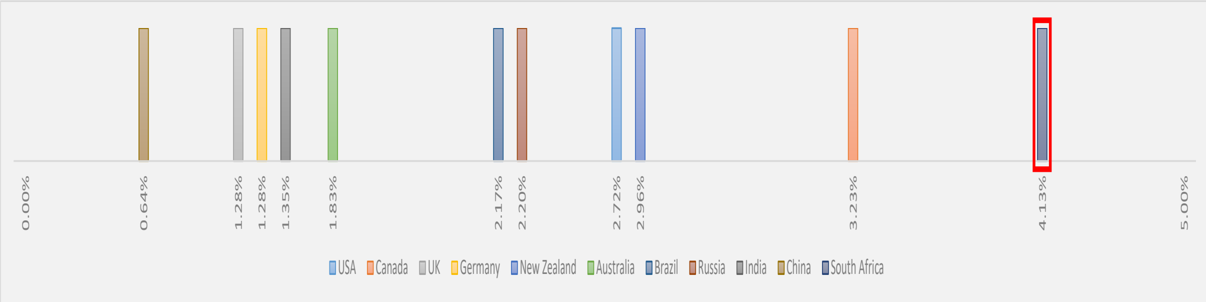


Figure 5.3 | Percentage of annual salary spent on fuel

(Source: Randal, McIntyre and Diamond, 2016)

Measuring the price of fuel in South Africa in terms of the share of personal revenue absorbed by fuel for travel illustrates the true cost to road users. Given the regressive nature of fuel levies, any increase in the price of fuel would therefore also affect poorer communities severely.

5.4.1.2 Magnitude of transport costs on individual and household budgets

Using revenue and expenditure data from Statistics South Africa (2011), it is possible to determine empirically the magnitude of transport costs, the fuel levy in particular, and their effect on individual and household budgets. For comparative purposes, the expenditure of the average South African was compared to that of the average vehicle user and to a hypothetical vehicle user operating an electric vehicle (see Figure 5.4).

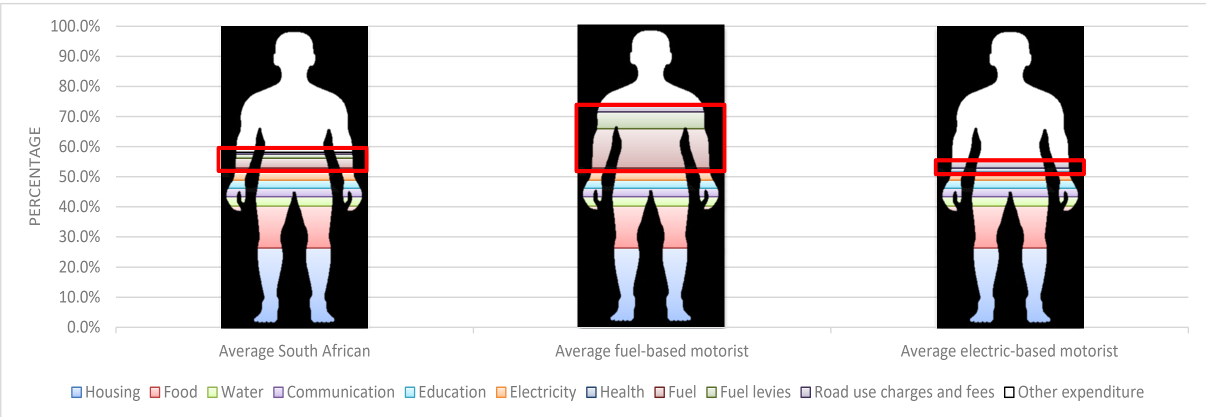


Figure 5.4 | Income and expenditure of average road user

The average South African household incurred an average annual household consumption expenditure of R116 381 in 2014 (projected using "Income and Expenditure Survey 2010-2011" data using an average inflation rate of 5.4%). Of this amount, the three biggest expenditure items were housing (26.3%), transport (17.1%) and food (13.9%). Transport expenditure includes the purchase of vehicles such as motorcars, motorcycles and bicycles, the purchase of transport services that mainly relate to the fares of public transport and the operation of personal transport equipment. The latter comprised spare parts and accessories, maintenance and repairs of the personal transport equipment, and expenditure on fuels and lubricants. Expenditure on fuel was 4.6% of the average annual household consumption expenditure. Of this 4.6%, the general fuel levy comprised 0.9%, Road Accident Fund Levy, Demand-Side Management Levy, IP Marker Levy and Petroleum Products Levy constituted a further 0.5%, resulting in 1.4% spent on fuel levies and taxes (thus 4.6%–1.4% = 3.2% is therefore the expenses on the base cost of transport). Additionally, 0.6% was spent on selected road user charges and fees.

Assuming this expenditure and an average fuel price of R12.06 and vehicle fuel efficiency of 12l/100 km, the average South African travelled 3 726 km while using 458 litres of fuel in 2014. This discussion relates to the average South African as characterised by a specific revenue and expenditure profile. A private vehicle owner, however, is more likely to travel approximately 15 000 km per year and use 1 800 litres of fuel. Assuming the same revenue and expenditure levels as the average South African, expenditure on fuel (excluding fuel levies) would increase to 13.1%. The motorist would also pay 5.6% towards fuel levies and 2.4% towards road user charges and fees such as speeding fines and parking costs. The fuel levy alone would account for 3.8% of the annual expenditure. Expenditure on fuel-related and vehicle use-related taxes would comprise 21.1%, a rather worrisome and unsustainable tax burden. This illustrates the financial position of the average South African with regard to road user charges and taxes. Coupled with long travel distances, the cost of private vehicles is a significant financial undertaking for the majority of South Africans.

A hypothetical motorist operating an electrical vehicle, travelling on average 15 000 km and assuming the same annual expenditure, would use no fuel and spend 0% on fuel levies, including the fuel levy. They would spend 2.4% on road user charges and fees because of operating the vehicle on the road network.

While this section addresses the issue of what government *collects* and what is spent on roads, both in aggregate terms and per vehicle km, it does not address what road users should be paying based on equitable and efficient road pricing principles.

5.4.2 Deriving a short-run MSC-based road user charge

While some costs are known, such as the annual maintenance costs (from audited accounts), most road use costs are not, preventing the exact estimation of an accurate road user charge. In other instances, aggregate costs estimates are available, such as the cost of accidents to the South African economy (R147 billion per annum in 2016), but these estimates should be treated with circumspection, as they do not reflect the external costs associated with road users, and because the calculation of the specific costs has not been ratified by the accepted methodology. Finally, an often wrongly understood system is the inclusion of capital infrastructure costs in road user charges. As discussed above, in setting road user charges, the existing capital asset base is not regarded. In road user charges, only the costs attributable to the road user, i.e. direct maintenance, some upgrade costs and other external costs, are included. Historical investment costs are not included or, if they are, they are often negligible in road user charges. However, firstly historical cost may provide an indication of how a private entity will set tariffs and, secondly, may provide an indication of what revenue is required to maintain the current asset in an agreed state (Newbery, 1998).

South Africa had an estimated 746 835 km of roads, with a potential value of R2 trillion in 2014 (National Treasury, 2015). This represents the sunk costs (road capital costs). The existing maintenance backlog is projected to be roughly R200 billion. With the historical cost method of pricing, sunk costs are spread over time between successive generations of users using a representative discount rate. Using a discount rate of 8%, the total annual road cost (2014) was R206 093 313 914 (assuming the backlog would be addressed first). Considering the estimated total distance travelled in 2014 as 162 405 499 396 km, this results in a per km cost of R1.27 for the average vehicle. This amount is required to maintain the road network in its current state. Allocating revenue to the road sector of less than this amount will lead to a gradual decline in the condition of the road network. It does not represent the amount the user should pay but rather the average amount that the state and the user should contribute to roads.

As shown earlier, the total direct revenue (R0.62 per vehicle km) collected in 2014 amounted to R100.9 billion. Additionally, indirect revenue (revenue not relating to actual road use, but vehicle ownership) to the amount of R66.5 billion was collected in the same year (R0.40 per vehicle km). This amounted to a total of R166 414 285 000 or R1.02 per km. If the historical costs are assumed, users (i.e. all vehicle types on average) are contributing R0.25 per km less than the required R1.27 per km to maintain the road network asset without considering the operational costs. Not all operational costs should be attributable to the road user, assuming a 10% allocation or R0.05 per km for operational costs, resulting in a road user cost of R1.32 per km and a deficit of R0.30 per km.

Deriving the MSC of road use is a complicated and time-consuming task and estimates of MSC are scarce. The best source of reference values was probably produced by the European Commission and was based on extensive and comprehensive research and consultation amoung all EU countries (Doll & van Essen, 2008; van Essen, Schroten, Otten, Sutter, Schreyer, Zandonella, Maibach & Doll, 2011; Korzhenevych *et al.*, 2014). It is therefore not feasible to determine MSC for South Africa within this study. What is possible is to consider international values of MSC and based on these derive corresponding estimates for South Africa based on local data.

5.4.2.1 Marginal infrastructure cost

Road maintenance costs in South Africa amount to roughly R49 billion. This entry in the national accounts, however, also includes new construction and road upgrades. Assuming that 45% of the annual road maintenance cost is spent on maintenance, the marginal infrastructure cost is roughly R0.14 per km. Furthermore, the operational cost of R70 billion cannot all be attributable to users and included in the MSC. Assuming that 10% of these costs can be attributed to use by an individual user, it will result in a road user cost of R0.04 per vehicle km. Marginal (or additional) infrastructure costs are therefore roughly R0.18 per vehicle km.

5.4.2.2 Marginal congestion cost

Congestion costs, made up of travel time, vehicle operation costs and the inconvenience to all the road users who are impacted by the addition of one additional vehicle to the flow, can overshadow all other elements of MSC, i.e. accident costs, noise and air pollution. This is subsequently the reason for the popularity of congestion charges, and their relative acceptability to the community, to curb congestion in urban areas.

The cost of congestion to the South African economy has seen wide ranges of speculative values ranging from R1 billion to R60 billion annually. The vast difference in these estimates may be based on the frequent mistake of the assumption that no congestion (i.e. free flow) is efficient, which in reality is not. No formal congestion studies have, however, been undertaken in South Africa. Data for the EU indicate that the cost of congestion, measured per vehicle km, can vary significantly. Accepting R60 billion as the best guesstimate of congestion costs in South Africa would mean an average cost of R0.37 per vehicle km.

5.4.2.3 Marginal accident cost

Recent work from the Road Traffic Management Corporation in South Africa revealed the annual costs of road accidents to be R142.95 billion, equating to 3.4% of GDP. This translates into a per km charge of R0.78 (when discounted to 2014). This cost, however, cannot be assumed the external cost of accidents and is merely the average cost per vehicle km. The external cost will require an assessment of the degree of risk internalisation of accidents (i.e. own insurance) and the risk associated with each vehicle and driver. Such an exercise was not possible in the context of this study. Assuming EU values for South Africa and combining this with research undertaken at Stellenbosch University, the per km cost for accidents is likely to be in the range of R0.01 – R0.15 (assuming a value of R0.09 per km for calculation purposes).

5.4.2.4 Marginal environmental (noise and pollution) cost

Only limited work has been done in South Africa with regard to the environmental costs (pollution and noise) associated with transport in general and road transport in particular in South Africa. Several environmental models such as the COPERT 4 (Computer program created by the European Environment Agency to calculate emissions from road transport) model have been applied to the sector in South Africa. Furthermore, the Automobile Association of South Africa (AA) publishes vehicle emissions for all South Africa vehicles (comparative fuel economy for passenger cars and information on CO_2 emissions). Using the AA data, external costs were estimated for South Africa using distance travelled per vehicle type and CO_2 equivalency factors. A cost of R476.79 per tonne CO_2 was used to determine a per km cost of R0.13. Unfortunately, no noise data was available.

5.4.2.5 Total MSC

The summation of the cost components per vehicle km, i.e. infrastructure operations and maintenance (R0.18), congestion (R0.37), accidents (R0.09) and pollution (R0.13), results in a cost of +/- R0.77 per vehicle km. This should be compared to the R1.02 that road users in South Africa are already paying towards road use (both in indirect and direct charges) and the R1.27-R1.32 to maintain the network. Note that these values have been averaged over different vehicles, times of the day and types of road. It serves merely as an illustration of the system.

If capacity is not optimally adjusted to demand, for example, low demand with excess capacity, setting optimal road user charges will lead to deficits. South Africa has a large road network with a comparatively small vehicle population. Charging a road user fee that excludes the external cost component will clearly not deliver sufficient revenue. Implementing congestion charges, and other external costs, with road damage charges, however, may address part of this problem.

5.4.2.6 Variable MSC

Using the data supplied for the EU, Table 5.1 illustrates the dramatic differences in MSC between a car and a heavy goods vehicle that travel in and outside of the peak hour, on different road types and in different regions. Congestion cost is the main contributor to peak cost values. Equivalent values for South Africa were derived using an exchange rate of R14.59 to the Euro and using PPP.

Table 5.1 | Derived short-run MSC-based congestion charges for South Africa (2014) (Sources: Doll and van Essen, 2008; Korzhenevych *et al.*, 2014)

	Region.	Road type	Free flow	Near capacity	Over capacity
			(R/km)	(R/km)	(R/km)
Car	Metropolitan	Motorway	R0.00	R2.44	R5.63
		Main roads	R0.08	R12.93	R16.58
		Other roads	R0.22	R14.59	R22.19
	Urban	Main roads	R0.05	R4.45	R6.94
		Other roads	R0.22	R12.76	R21.09
	Rural	Motorway	R0.00	R1.22	R2.81
		Main roads	R0.03	R1.67	R5.55
		Other roads	R0.01	R3.84	R12.74
Rigid truck	Metropolitan	Motorway	R0.00	R4.65	R10.69
		Main roads	R0.16	R24.57	R31.51
		Other roads	R0.43	R27.72	R42.17
	Urban	Main roads	R0.10	R8.46	R13.18
		Other roads	R0.43	R24.24	R40.08
	Rural	Motorway	R0.00	R2.32	R5.34
		Main roads	R0.07	R3.18	R10.55
		Other roads	R0.03	R7.30	R24.20
Articulated truck	Metropolitan	Motorway	R0.00	R7.10	R16.32
		Main roads	R0.24	R37.50	R48.10
		Other roads	R0.66	R42.32	R64.37
	Urban	Main roads	R0.16	R12.91	R20.12
		Other roads	R0.66	R37.00	R61.18
	Rural	Motorway	R0.00	R3.55	R8.16
		Main roads	R0.11	R4.86	R16.10
		Other roads	R0.05	R11.15	R36.95
Bus	Metropolitan	Motorway	R0.00	R6.12	R14.07
		Main roads	R0.21	R32.32	R41.46
		Other roads	R0.56	R36.48	R55.49
	Urban	Main roads	R0.14	R11.13	R17.35
		Other roads	R0.56	R31.90	R52.74
	Rural	Motorway	R0.00	R3.06	R7.03
		Main roads	R0.09	R4.19	R13.88
		Other roads	R0.04	R9.61	R31.85

Table 5.1 does not show what MSC in South Africa should be. It is simply an illustration of MSC ranges for road use in the EU and South African comparison values based on PPP. Note that while these values do not hold any relevance for South Africa, they demonstrate how road user charges are impacted by location, time of day and vehicle characteristics, and specifically congestion on road user charges.

These results clearly indicate the very different outcomes that can be obtained using the different approaches and the sensitivity of the final road user charge to the available cost data.

However, the findings do seem to indicate, simply based on comparison with international data and road user charges, that South Africans are already paying a fair price for road use in rural areas but that urban and peak hour road user charges may not cover road user costs.

Implementing such a road user charge would make road users aware of their congestion costs and it may entice more sustainable driving behaviour, such as choosing public transport in urban areas. It may also shift trips to the off-peak, thereby reducing congestion. The problem in South Africa may be less a question of additional or increased road user charges and more an issue of differentiated charges between urban and rural areas and between congested and non-congested roads and the allocation of road funds. In congested urban environments and the main metropolitan highways, the situation may be different and current road user charges may not adequately reflect the congestion caused by vehicles. An important caveat for implementing road user charges based on MSC is that the pricing principle should be followed by all modes and services. Implementing the user pay approach based on the principle of MSC also does not guarantee that costs will be covered (or in fact that they should be covered).

The user-pay approach, if equated to the internationally accepted term of MSC as a road user charge, will cover road user costs, but the principle does not guarantee sufficient revenue or budget neutrality. In fact, applying the user-pay approach may lead to a decrease in revenue from road users in some areas, notably rural areas and off-peak travel, while it may lead to an increase in revenue in urban areas and on the main highways experiencing congestion. Road usage charges should not be set at a minimum below the variable cost of the used road, i.e. the MSC. Local taxes and charges can be used to promote lightly travelled local access roads and cover all road usage costs associated with the provision of such roads. Congestion costs should be included in road use charges in congested cities and high volume roads (Heggie & Vickers, 1998).

South Africa is not unique in its road-funding dilemma. Few countries manage to balance revenue from road users with demands for road funding. While there is no clear recipe for success, it seems that countries that do implement the user-pay approach, based on the system of MSC, seem to be more successful in getting the prices right, i.e. fair and efficient road user charges.

Marginal social cost as presented in this section will lead to fair and efficient prices or road use charges for road users. While the principle is quite clear, the current road user charging institutional framework in South Africa is not receptive to such an approach. Road use charges and road ownership taxes are collected at various levels of government and have no relationship with the actual costs imposed by road users on society. Any connection between efficient road user charges and the current road user taxes and levies is merely spurious.

5.5 Discussion and conclusion

Transport infrastructure, roads in particular, affects economic growth by lowering transaction costs and ultimately improving productivity. In addition to the direct and even some indirect effects such as employment creation, transport infrastructure also supports trade, competitiveness, regional integration and tourism, which are all important developmental objectives that are part of the NDP.

South Africa appears to spend many funds on roads, particularly administration and regulation, but also on road maintenance and construction. Despite this, the country is faced with a rapidly deteriorating road network, increasing congestion in the urban areas and an insubstantial national road funding policy. The country cannot rely on the current national road-funding framework to finance or manage its roads. To replace the current approach, a policy is proposed founded on the principles of i) efficient road user charging to regulate the demand for road capacity based on MSC, ii) efficient investment to minimise the total public and private investment in road capacity and iii) efficient road management to coordinate road user charging and investment. An effective road funding policy is dependent on close cooperation between these three elements. Implementing one without the other will not deliver any results and may in fact be counterproductive.

While SOEs have been in the news for all the wrong reasons, reforming the roads sector in South Africa will probably result in some additional (although functioning independent) parastatals such as a Road Users Authority, Road Fund Administration and Road Fund. The National Treasury and the Department of Transport should transfer to them the responsibility for managing, financing and maintaining the roads. These entities should establish a system of road user charges based on the MSC principle. Heavy vehicle (> 3500 kg) weight-distance charges and congestion charges are well-known and practical road cost recovery methods that can be effectively implemented. Shortfalls should be covered by transfers from the National Revenue Fund and not imposed on existing users.

South Africa seems to have reached a critical point with regard to road funding. It is unclear whether roads are currently allocated sufficient funds. All indications are that the country allocates a comparable amount of funds to the roads sector. What did become glaringly clear during the study is the absolute lack of general knowledge about how much money is spent on roads, the requirement for funding, how much users are spending and how the funding cycle works. In South Africa, the responsibility for establishing a road funding policy, setting road user tariffs, managing the road funding budget, collecting data and disseminating reports to the public, and even simply stating the case for roads seems disjointed. No single authority seems to take responsibility for these tasks. The solution to road funding in South Africa is therefore not only a monetary problem but also a knowledge problem. It is firmly recommended that the institutional and policy framework should be addressed before any funding issues are considered.

The following chapter continues to evaluate the appropriateness of DBRUC by assessing to what extent South African road users view current and proposed road cost recovery methods within the country's road-funding framework.

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Appendix 5.A | Efficient marginal congestion costs, €ct per vehicle kilometre, 2010, European Union average

Vehicle	Region	Road type	Free flow	Near capacity	Over capacity
			(€ct/vkm)	(€ct/vkm)	(€ct/vkm)
Car	Metropolitan	Motorway	€ct 0.0	€ct 26.8	€ct 61.5
		Main roads	€ct 0.9	€ct 141.3	€ct 181.3
		Other roads	€ct 2.5	€ct 159.5	€ct 242.6
	Urban	Main roads	€ct 0.6	€ct 48.7	€ct 75.8
		Other roads	€ct 2.5	€ct 139.4	€ct 230.5
	Rural	Motorway	€ct 0.0	€ct 13.4	€ct 30.8
		Main roads	€ct 0.4	€ct 18.3	€ct 60.7
		Other roads	€ct 0.2	€ct 42.0	€ct 139.2
Rigid truck	Metropolitan	Motorway	€ct 0.0	€ct 50.9	€ct 116.9
		Main roads	€ct 1.8	€ct 268.5	€ct 344.4
		Other roads	€ct 4.7	€ct 303.0	€ct 460.9
	Urban	Main roads	€ct 1.2	€ct 92.5	€ct 144.1
		Other roads	€ct 4.7	€ct 264.9	€ct 438.0
	Rural	Motorway	€ct 0.0	€ct 25.4	€ct 58.4
		Main roads	€ct 0.8	€ct 34.8	€ct 115.3
		Other roads	€ct 0.4	€ct 79.8	€ct 264.5
Articulated truck	Metropolitan	Motorway	€ct 0.0	€ct 77.6	€ct 178.4
		Main roads	€ct 2.7	€ct 409.8	€ct 525.6
		Other roads	€ct 7.2	€ct 462.5	€ct 703.5
	Urban	Main roads	€ct 1.8	€ct 141.1	€ct 219.9
		Other roads	€ct 7.2	€ct 404.4	€ct 668.6
	Rural	Motorway	€ct 0.0	€ct 39.8	€ct 89.2
		Main roads	€ct 1.2	€ct 53.1	€ct 176.0
		Other roads	€ct 0.6	€ct 121.9	€ct 403.8
Bus	Metropolitan	Motorway	€ct 0.0	€ct 66.9	€ct 153.8
		Main roads	€ct 2.3	€ct 353.3	€ct 453.1
		Other roads	€ct 6.2	€ct 398.7	€ct 606.4
	Urban	Main roads	€ct 1.6	€ct 121.7	€ct 189.6
		Other roads	€ct 6.2	€ct 148.6	€ct 576.3
	Rural	Motorway	€ct 0.0	€ct 33.5	€ct 76.9
		Main roads	€ct 1.0	€ct 45.8	€ct 151.7
		Other roads	€ct 0.5	€ct 105.0	€ct 348.1

Chapter 6. Gathering public opinion on road cost recovery methods in South Africa[1]

This study identified DBRUC, in Chapter 1 as a road cost recovery method, which could be implemented within the current South African road-funding framework to possibly secure funding from road users to meet the road sector's expenditure requirements. This study then set out to evaluate the need, appropriateness and practicality of DBRUC using GPS-enabled vehicle tracking devices and a short-run MSC-based fare structure as a road cost recovery method in the South African road-funding framework by providing objective research on whether this road cost recovery method should be implemented in South Africa. Chapter 2 in turn presented a comprehensive literature review to provide a clear understanding of DBRUC and where it fits into the road-funding environment, discussing the existing knowledge and research on this system and identifying areas or challenges that require further research. An evaluation of the need for DBRUC followed in chapter 3 that assessed the extent to which the South African road-funding framework is able to secure funding for roads. Continuing this evaluation, Chapter 4 set out to assess to what extent the current South African road cost recovery methods will be able to secure funding for roads in the future given the emergence of disruptive transport technologies and societal trends. Chapter 5 then aimed to evaluate the appropriateness of DBRUC by assessed to what extent the South African road funding framework reflect fair and efficient road user charges. Chapter 6 aims to address research question 4, which continues to evaluate the appropriateness of DBRUC by assessing to what extent South African road users view current and proposed road cost recovery methods within the country's road funding framework.

The chapter starts by introducing the topic of gathering public opinion on road cost recovery methods in South Africa, while explaining its relevance to the study, stating the aim and objectives and outlining the main points of the research. Thereafter international public opinion studies on DBRUC are reviewed. It continues by providing a description of the research methodology employed to address the chapter's aim which include an online survey, outlining the objective of the method, describing the method design and limitation. This is followed by presenting the research results from collecting public opinion regarding the fuel levy and

[1] Sections of this chapter are contained in an article prepared for submission to a peer-reviewed journal.

DBRUC through an online survey distributed through newspapers, large employers and social media. This is done by assessing road user's awareness, knowledge, perception, attitude, acceptance and favourability of the road cost recovery methods through various questions. The chapter concludes with a discussion on how to increase public acceptance of road cost recovery methods.

6.1 Introduction

Over the years, the fuel levy proved to be an efficient road user charge, charging road users based on the amount of fuel they consume, which was historically aligned and standardised across all road vehicle categories. This created a general belief that it had, has and will continue to have the ability to serve as a road cost recovery method for many years to come. However, in South Africa, this trusted revenue source is facing a bleak future due to disruptive transport technologies, pushing it away from theoretical principles of paying for the use of public goods as discussed in chapters 4 and 5. This has created the requirement to find new revenue sources.

The efficiency of the fuel levies has decreased significantly over the past decade due to the ever-improving fuel economy of modern road vehicles. Although the fuel levy has increased significantly in terms of absolute income, even exceeding inflation, in relative income terms this has led to a decrease in revenue collected from users of the road network in South Africa.

The fuel levy contribute 47% to direct road user revenue generated each year, which is only capable of covering 40% of South Africa's road infrastructure expenditure (Department of Logistics, 2017).

Therefore, the requirement exists to explore a new cost recovery method, which is capable of ensuring long-term efficiency to fund South African roads, regardless of future social or technological trends.

A road user charge with newly found interest states that road users have to be charged according to the actual distance (km) travelled. This stands in contrast to the amount of fuel their vehicles consume. In addition to the fuel levy, the implementation of a DBRUC could serve as an ideal alternative to the funding problems that road networks currently face (Sorensen, Ecola, Wachs, Donath, Munnich & Serian, 2009). However, a road user charge system that aims to eventually replace the current fuel levy requires a gradual phase-in period mainly due to public support and acceptance issues relating to transparency and fairness. There is currently a knowledge gap in public perception and level of public acceptance towards a DBRUC system or any other road user charge method in South Africa for that matter. In order to fill this knowledge gap, it is required to assess and understand responses of the public towards the fuel levy and a DBRUC.

A DBRUC system allows a pricing strategy, which is internalised and marginal. Road users are charged based on the actual km driven rather than the amount of fuel they use. Pilot projects related to charging per distance travelled is being explored by various countries worldwide, especially the USA. However, this is not the case in South Africa. In order to delve into this system, various interconnected components of a DBRUC should be identified and explored to be able to assess its practicality as a cost recovery method for road funding in South Africa. Gaining comprehensive knowledge about these components can be seen as challenges that have to be overcome to guarantee that a DBRUC is implemented seamlessly. One of these components, which is very often overlooked by initiatives, entails maximising public acceptance and gaining insight into the opinions of the public. Essentially a tax system works if the public understands the concept. Understanding the dimension of public perception and acceptance in order to win support from the public is a critical consideration, especially in South Africa. The e-toll fiasco can be used as an example to highlight the importance of gaining public support. In 2015, Opposition to Urban Tolling Alliance (Outa[2]) confirmed that one of the five major factors why the e-toll system in Gauteng, South Africa, failed was due to a lack of buy-in from the general public (Du Preez, 2015). These consequences of public rejection, together with the country's high levels of protest action, highlight the importance of assessing road user perception in South Africa (Duvenage, 2013).

Many road users are unaware of how roads are maintained and how the revenue generated from the fuel levy is spent. The South African fuel levy is allocated to the general budget, not earmarked and not directly spent on roads. Furthermore, many people have not yet come to the realisation that the long-term viability of the existing road funding system is declining. Public outreach and education are key prerequisites to convey the importance of accepting and supporting a DBRUC system as a means of securing general revenue that can be used to fund road maintenance and public transport infrastructure. At current, knowledge on road user

[2] Name changed in February 2016 to Organisation Undoing Tax Abuse

opinion in South Africa is lacking.

Public opinion is seen as one of five major challenges in the implementation of a new road user charge system. The other challenges include technology, pricing policy, privacy protection and institutional relationships (Nordland, Paz & Khan, 2013). An important consideration that should be considered is that the public will require time and motivation to adapt to change. The purpose of this chapter is to present the findings of a survey to gauge how the public considers a new approach compared to the current fuel based taxes.

Therefore, this chapter aims to continue to evaluate the appropriateness of DBRUC by assessing to what extent South African road users view current and proposed road cost recovery methods within the country's road-funding framework. This will be done by i) collecting public opinion regarding the fuel levy and DBRUC through an online survey.

6.2 Literature review

The literature review briefly provides an overview of public opinion on DBRUC, mainly from an American perspective, by discussing results from studies conducted in the USA.

6.2.1 International public opinion on DBRUC

Road user charges is a common topic in the academic research world, which includes a considerable amount of literature that tends to focus on public acceptance and opinion (Jaensirisak, Wardman & May, 2005).

Iowa University performed a two-year field survey that began in 1999. It primarily focused on the technical consideration and user acceptance of a distance-based road charge system as a future road funding option for replacing the current vehicle fuel levy (Hanley & Kuhl, 2011). This allowed the study to address two major concerns regarding such a policy: i) technology appropriateness and ii) user acceptability and accessibility. An on-board computer (containing GPS receivers) was installed in participants' vehicles to track the distance covered by each participant. This allowed the study to collect data from both the technology as well as participants. Approximately 2 650 volunteers from 12 areas across the USA participated in the study. The researchers highlighted two attributes that are crucial to maximise public support and acceptance of the new approach. The first attribute involves that the road use data, which is stored on the tracking device and transmitted to the collection centre, should be as non-specific as possible. The second attribute involves that the collection centre, responsible for data processing, should be operated privately under a strict set of controls.

As early as 2001, Oregon investigated alternative road funding methods to address the road funding gap in the USA context. On 1 July 2015, the Oregon Department of Transportation launched the nation's first new road user charge model called OReGO (Jones & Bock, 2017). The model is operational and allows volunteers to pay a road user charge based on miles driven instead of paying the fuel levy. When Oregon first started experimenting with a distance-based fee pilot model, public acceptance was regarded as one of the main issues (Whitty & Imholt, 2007). The programme took place over a 12-month period and included 299 vehicle-owning volunteers as well as two service stations in Portland. Gaining a unique understanding about public concerns, required Oregon's Department of Transportation to communicate effectively with the motoring public for six years. Policy makers had to ensure that public concerns were addressed adequately before a distance-based fee system could be put in place. The pilot programme found that the major barriers to public support were privacy protection, rate equity, fairness, technology reliability and costs.

The Minnesota Department of Transport conducted a DBRUC public opinion study, called pay-as-you-drive (PAYD) (Fichtner & Riggleman, 2008). The primary objective of the study was to evaluate how Minnesota's public would respond to a VMT user charge to obtain a better understanding of their perceptions and level of acceptance towards a VMT system. The study's methodology followed a qualitative research approach, which collected information through discussion groups. A total of 60 Minnesota drivers participated in nine mini focus group sessions from 11 August 2008 until 21 August 2008. The study concluded with the following main findings concerning user perception: i) Public education about the concerned matter is a prerequisite, including why the required change is required; ii) The new VMT user charge system should be phased in gradually; and iii) The public should be familiarised with each stage before proceeding to the next.

In 2013, the University of Indiana conducted a study to investigate the extent to which the public will support a distance-based road user charge as a substitute for the current fuel levy (Duncan, Nadella, Giroux, Bowers & Graham, 2017). The purpose behind the study was to address the problem of inadequate road funds currently faced by states across the USA. Data was collected through a nationally representative public opinion survey to answer the research questions.

The study suggested that policy-makers should carefully consider the following: i) the design of the user-fee and ii) the inclusion of informational campaigns to address public concerns. As revealed by the study, support intensity was weaker than the opposition intensity. Subsequently, the results concluded that the public is unlikely to adopt a distance-based road user charge anytime soon.

Agrawal and Nixon (Agrawal, Nixon & Hooper, 2016) identified several research gaps for future research that were not present or adequately researched in previous public opinion studies. The authors performed a synthesis review of several public opinion studies regarding distance-based user fees and found: i) a lack of research into the opinions of what they call "important subgroups of the population" referring to low-revenue and minority residents, or present findings of subsets of respondents defined by revenue, race, or ethnicity; ii) the research also does not distinguish between rural vs urban residents and the perception that DBRUC may have different impacts on them; and iii) a number of issues and concerns have not been addressed and most of the surveys asked only about support or opposition to distance-based road user charges in general and lacked numerous other concerns like privacy, fairness and administration. Furthermore, they suggested numerous topics that could also be explored through survey research:

1. How a respondent's knowledge about current transportation revenue options influence support for distance-based road user charges should be considered;
2. Only descriptive statistics or simple bivariate analysis are present in most current study research. Multivariate analyses are required to better comprehend how variables such as demographic features, travel behaviour, owned car type and attitude affect public opinion on road user fees; and
3. Relatively little information is available about DBRUC pilot programme participants. More pilot programmes that include comprehensive public opinion research would be helpful, as the opinions of these respondents could be particularly useful in anticipating how the government would respond if a distance-based user fee were effectively enforced.

Through a synthesis analysis of twelve qualitative research studies, thirty-eight government opinion surveys and a total of 359 press articles they discovered that the bulk of the public still do not support a DBRUC system with an average approval of only 24 percent, ranging from 8%

to 50%. With regard to the issue of whether individuals support the overall notion of a DBRUC that replaces the fuel levy the average support was 23%, ranging from 8% to 42%. Additionally, the public was concerned with privacy, fairness and administration of the road cost recovery method.

6.3 Research methodology

To evaluate the appropriateness of DBRUC by assessing to what extent South African road users view road cost recovery methods within the country's road-funding framework, an online survey was undertaken. The research methodology briefly provides an overview of the technique employed, where after the technique are discussed in terms of its objectives, the method employed as well as the limitations of the method.

6.3.1 Online survey

6.3.1.1 Objective of method

The online survey, Appendix 6A, intended to gauge public opinion regarding the fuel levy and DBRUC. The survey questionnaire posed questions to respondents related to their awareness, knowledge, perception, attitude, acceptance and favourability toward the well-known fuel levy and the relatively unknown DBRUC system. Firstly, the questionnaire set out to ask the respondents demographic questions to assess whether demographics influence the opinions. Secondly, questions related to awareness of the fuel levy and DBRUC to assess respondents' informed interest of the particular road cost recovery method and if they are aware that the method might be experiencing efficiency problems or might be a better road cost recovery option for them. Thirdly, questions related to knowledge of the two road cost recovery methods to assess respondents' deeper understanding mainly related to their theoretical and practical understanding of the road cost recovery methods.

Fourthly, questions linked to their perception of different attributes of the fuel levy and DBRUC to assess the respondents' viewpoint or how each method is regarded, understood and interpreted. The perception of 12 declarations relating to charging characteristics was evaluated in a section in the questionnaire requesting satisfaction ratings (from "strongly agree", "agree" to "neutral/do not know"). Following the satisfaction rating, the participants had to indicate their importance in the charging attribute (from "very minor", "important", "neutral/do not know", "important" to "very important"). In Behrens, Schalekamp and

Wilkinson (2011), this technique is explained as a traditional approach to "satisfaction and importance [of] data analysis". In a market research paper, Martilla and James (1977) also presented the technique as a quadrant model. The technique shows satisfaction and importance for various charging attributes in four quadrants. These quadrants were labelled as "maybe overcrowding", "low priority", "keep a good job" and "centric here". In addition, Behrens, Schalekamp and Wilkinson report that Bacon and Jones (2003) have identified two alternative approaches to quadrant delimitation: "scale-centered" and "data-centered". The previous plots quadrant on the midway point rating scale (three on a Likert five-point scale). The second plots quadrants based on a data centre (i.e. an overview of the mean of all satisfaction ratings with the mean of all importance ratings). The "concentration here" quadrant attributes were highly important and highly unsatisfactory. This data analysis technique has made it possible to identify the attributes of a product or service that are in more requirement for improvement or which are candidates for cost-saving actions without significantly affecting the overall quality of the product or service.

Fifthly, questions related to the respondent attitude towards the two road cost recovery methods to assess the respondents' actions due to their perceptions of the road cost recovery method. This was asked to assess the potential effectiveness of this method for changing travel behaviour. This can be good or have unintended effects whereby road users will travel less and thus the road cost recovery method will generate less revenue. Sixthly, questions related to the respondents' acceptance of these two road cost recovery methods to assess if the respondents perceive the cost recovery method as adequate, valid or suitable. It is envisaged that the usage of a DBRUC would be unfavourable at first according to international studies. Lastly, a question related to the favourability of selected road cost recovery methods that the country could use including the proposed DBRUC system to assess the respondents' preferred choice of payment method for their road use (see appendix 6A).

6.3.1.2 Description of method

In the three months leading up to the collection of the online survey data, i.e. between May and July 2018, a pilot survey was conducted to test the online survey questionnaire (n=13) by sending a link that directed respondents to the online survey, facilitated through Checkbox® Survey, to selected individuals from within the academic and transport sector. During this process, no significant problems were encountered with either the operational activity or the survey questionnaire itself, but attention was paid to the respondents' suggestions and small corrections/adjustments made to the questionnaire where required. The main online survey (n=619) was undertaken in the three weeks between 13 August 2018 and 2 September 2018. During this period the survey was accessed by 1674 respondents of which 1031 respondents agreed to take part in the survey. By the end of the survey period a total of 619 surveys was completed successfully, 397 surveys was incomplete and 15 surveys was not attempted.

The online survey was made public through three communications streams. In the first week, an advertisement with a short description of the study to be undertaken and a link that directed respondents to the online survey was published in three major newspapers that circulate within the Western Cape. These included Cape Times, Cape Argus and Die Burger with a combined average readership of 730 000 per day (SAARF, 2015). The advertisement was placed on the Monday, Wednesday and Friday in English in the Cape Times and Cape Argus and in Afrikaans in Die Burger given their readership profile. The response was very low and only 49 usable responses was obtained. A possible reason for the low response was the need to type the survey link into an internet browsers. The advertisement was forwarded to large employers mainly within the transport sector in the Western Cape, such as the Provincial Department of Transport and the Southern African Bitumen Association, in the second week who were asked to distribute the survey through a snowball effect to fellow colleagues and contacts. This process delivered the largest response rate (n=498). In a last attempt to collect responses from the general public, the advertisement with the survey link was published with an article via University of Stellenbosch's social media platforms during the third week (n=72). Following the three-week data collection process, all questionnaire responses were captured in the Statistical Package for Social Sciences (SPSS). The data was cleaned and incomplete or spoiled questionnaire responses removed. A total of 619 valid responses was available and used.

HOW SHOULD OUR ROADS BE FUNDED?

Researchers at Stellenbosch University would like your opinion about two road funding methods. By completing a short survey of 10 to 15 minutes, you will help us gather valuable information on respondents' awareness, knowledge, perception, attitude, acceptance and favourability of these methods.

Please visit our website to complete the survey:
https://sunsurveys.sun.ac.za/Road_Funding.aspx

Figure 6.1 | Public Opinion online survey invitation

Given that the working population, aged 15 years and older, in the Western Cape is estimated to be in the region of 4 900 000 (Statistics South Africa, 2018), the margin of error of an envisaged convenience sample of 385 was estimated to be 5% at a 95% confidence level. The rationale for this population was that these respondents would travel to work using private or public transport and ultimately pay road user charges. Although in South Africa it is legal to work from the age of 15 years, care was taken only to target and accept responses from the population 18 years and older due to ethical issues. With the sample size of 619, the margin of error dropped to 4% at a 95% confidence level.

6.3.1.3 Method limitation

A limitation of this method was the willingness of participants to participate in the study. To counter this, the online survey questionnaire was designed to take no more than 10 to 15 minutes to complete. It still included critical questions to meet the objectives of the survey. A further problem that was foreseen was the technical difficulty some respondents may have found in understanding and answering the survey questions. To counter this, special care was taken to give respondents as little technical information as possible about both road user charge methods so as not to prejudice the responses. In addition, special care was taken with language editing the questionnaire to make it understandable to a wider audience.

6.4 Research results

The results section presents the findings from undertaking the online survey where public opinion on the fuel levy and DBRUC was collected. An overview of the demographic profile of respondents is provided where after road user's i) awareness, ii) knowledge, iii) perception, iv) attitude, v) acceptance and vi) favourability of the road cost recovery methods are discussed.

6.4.1 Collecting public opinion regarding the fuel levy and DBRUC

A total of 619 survey responses were collected, which included 49, 498 and 72 responses elicited through newspapers, large employers and social media respectively.

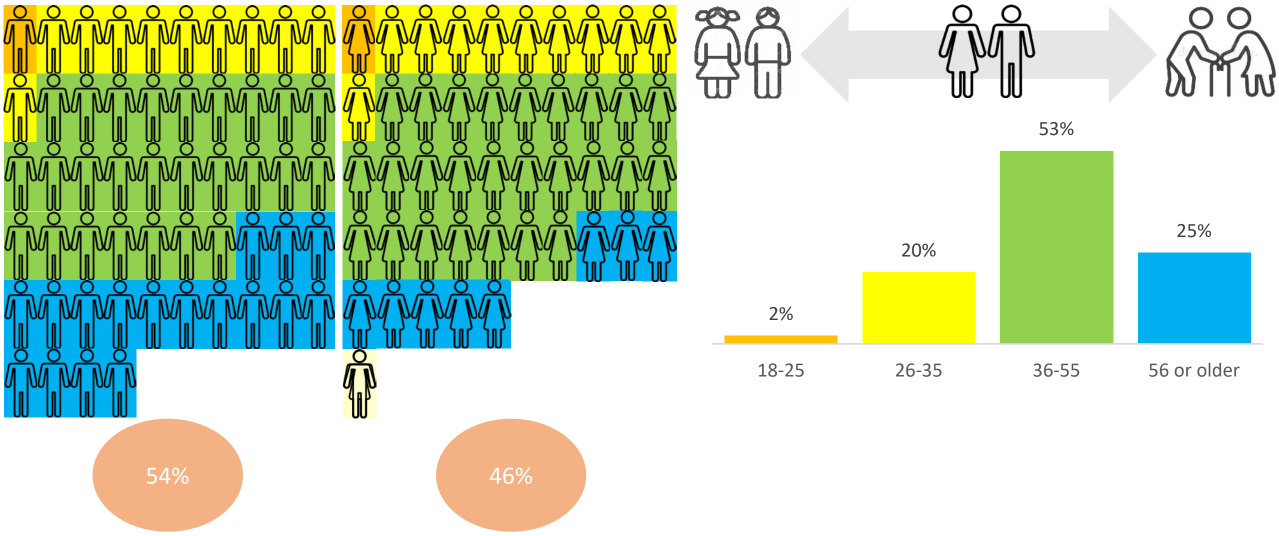


Figure 6.2 | Respondent demographics

Analysis of the survey data indicated that 54% of the respondents were male and 46% female. Over 73% of the respondents were between the ages of 26 and 55, with only 25% of them 55 or older. The survey data further reports that 95% of the respondents reported owning a vehicle and using the vehicle to travel on a daily basis (88%). The majority of respondents were from the Western Cape (91%), specifically the City of Cape Town Metropolitan Municipality (urban) area (79%).

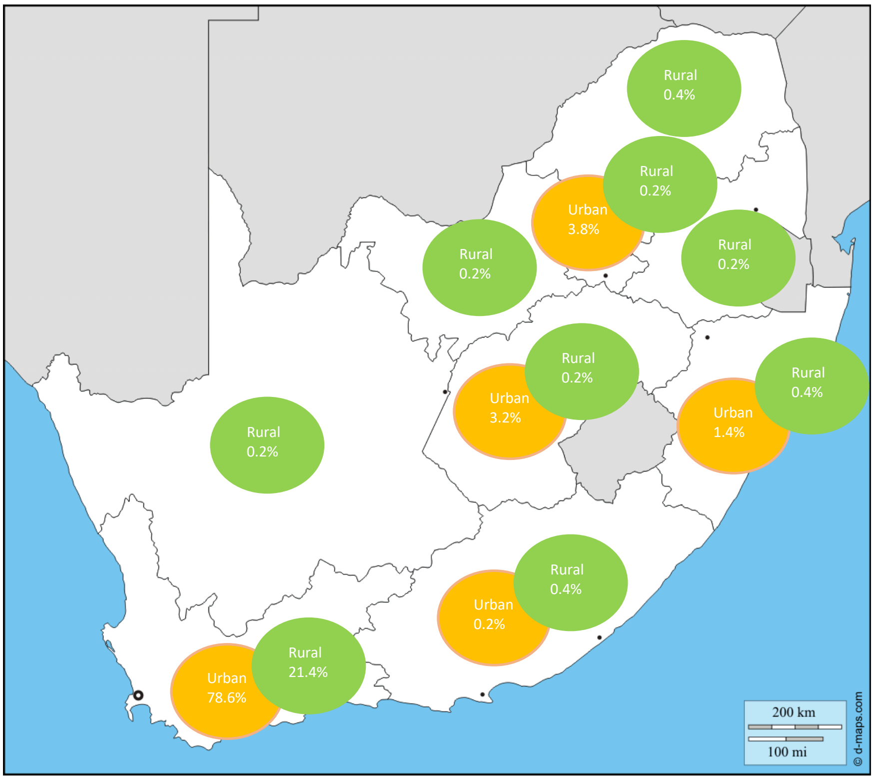


Figure 6.3 | Respondent location

6.4.1.1 Awareness

When the respondents were asked if they are aware that included in the price of fuel, they are paying for their use of the road network through a fuel levy, 90.5% of them indicated that they are aware but only 41.5% knew that the fuel levy is generating less revenue per vehicle km due to an increase in vehicle fuel efficiency and the increasing use of electric vehicles.

With a brief explanation of what DBRUC entails, the respondents further indicated that they are relatively unaware (69%) that a DBRUC may be a fair payment system for road use that would also generate sufficient revenue for improvements to roads and related transport systems.

6.4.1.2 Knowledge

Only 112 out of the 619 respondents (18.1%) indicated that they knew the share of the current fuel levy per litre of fuel that they purchase, but the data analysis revealed that only 23.2% of these respondents (26 respondents) stated the correct fuel levy amount of R3.37 per litre (for petrol) as at the time of the study.

Only 6.7% of all the respondents (40 respondents) indicated that they knew how much of the fuel levy they pay per km of road use. Fifteen per cent of these respondents indicated R0.35 per km of road use while most respondents (52.5%) indicated a value less than this. If assumed the average fuel consumption for vehicles in South Africa is 6.3 litres per 100km then the average motorist actually pays around R0.21 per km driven (Global Fuel Economy Initiative, 2018). As such, 65% of respondents overestimated the amount they actually pay while 32.5% underestimated this value.

More than half of the respondents (57.8%) said that they do not know what the fuel levy can be used for. Although not mutually exclusive, when asked to indicate for which programmes the fuel levy should be used, the respondents showed overwhelming support for roads (87.2%) and moderate support for public transport (52.2%). They did not favour general government expenditure (4%). Only 6.5% of the respondents indicated that all three programmes should be funded by the fuel levy.

A TURF[3] analysis showed that if government only used the fuel levy to fund roads, it would be accepted by 87.2% of all respondents. If government were to use the funds generated to additionally fund public transport, it would satisfy 90.5% of all respondents.

Of all the respondents, 76.3% did not know what a DBRUC system entails or how it would work. Although most questions on public opinion of DBRUC in the USA are based on the notion that a distance fee system should replace the current fuel levy, some institutions did ask additional stated-preference questions. The Minnesota Department of Transportation found in 2011 that 79% of respondents (from a sample of 400) were unfamiliar with the notion of paying by traveling distance. That was in the period when the American public were relatively unaware of any research or pilot programmes involving the new charging method. A similar observation was made two years later by Indiana University, which found that 81% of 2087 respondents have never heard or seen information about distance user fees. It was only in 2013 that the State of Oregon began researching distance fees through vehicle tracking and it was more widely reported on across the USA.

When asked if the respondents knew the exact amount that they had to pay per km to recover the cost of them using the road network, hinting that the cost includes externalities such as

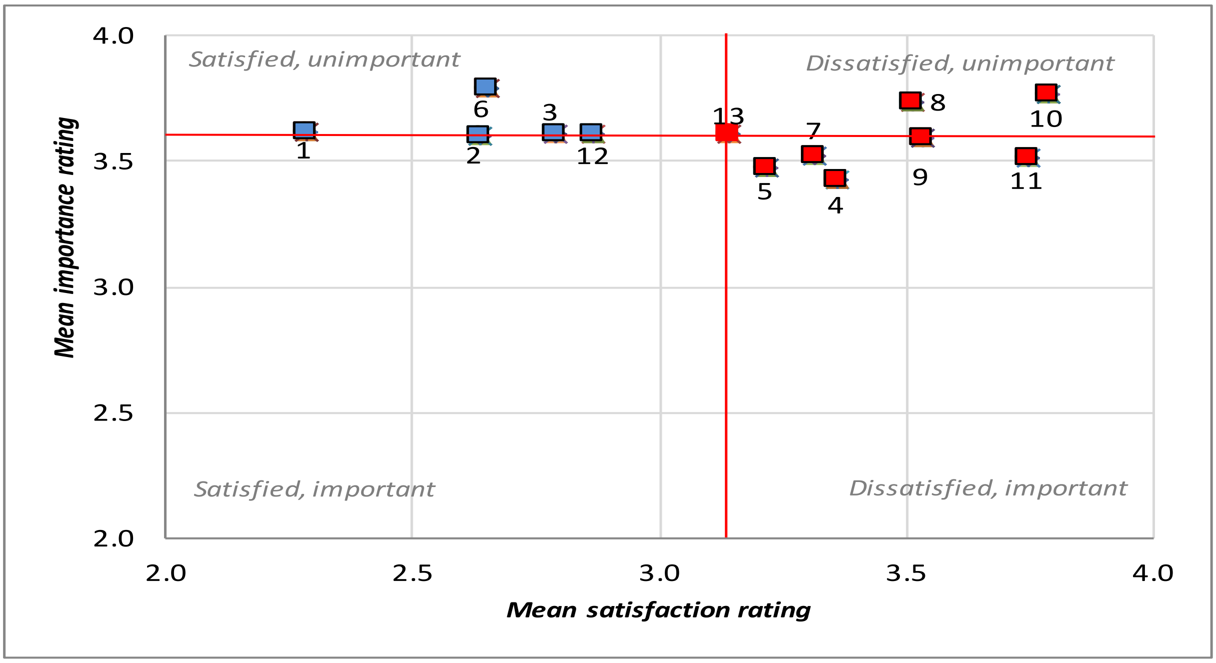
[3] TURF analysis is used to find the optimal sub-group of options from a wider portfolio to maximise their appeal to an audience or market.

congestion, environmental and accident cost, only 2.8% indicated that they knew this amount. This amount varies between R0.01 and R10.00.

Of the respondents in South Africa, 87.7% indicated that they do not know for what the road user charge that they will pay through a DBRUC can be used. When asked to indicate for which infrastructure programmes the DBRUC system should be used, the respondents were largely unsure with roads only receiving 10.8% support and public transport 7.2%.

6.4.1.3 Perception

The analysis indicates that the public is mostly concerned with the fact that they cannot easily calculate the fuel levy fee that they pay or must pay for each trip that they undertake. Furthermore, they do not think it is an efficient system to make road users aware of the total cost involved in using the road and as such do not use any appropriate technology to accurately calculate this cost. The public is furthermore also dissatisfied with the trustworthiness of the system and the fee levied is not transparent in how it is calculated or for what it is used. It is noted that the spread in dissatisfaction is much more than the spread in importance. This suggests that respondents are unsatisfied, but they do not have an answer. This may be an indication of ignorance or a symptom of corruption (Figure 6.4).



1 It is a simple system for charging road users for their use of the road.

2 It is an adequate system for ensuring a stable revenue stream from road users.

3 It is an equitable system whereby road users pay according to their

8 This system is trustworthy.

9 This system accurately determines the actual road-use cost incurred by the road user.

10 The fee charged per kilometre is transparent whereby I know

use of the road.

4 It is an efficient system that makes road users aware of all the costs involved for the road system.

5 The system uses appropriate technology to calculate the cost that we must pay for using the road.

6 The system is inclusive: all road users pay for using the road.

7 This system is acceptable to all road users.

which costs I incur and pay for.

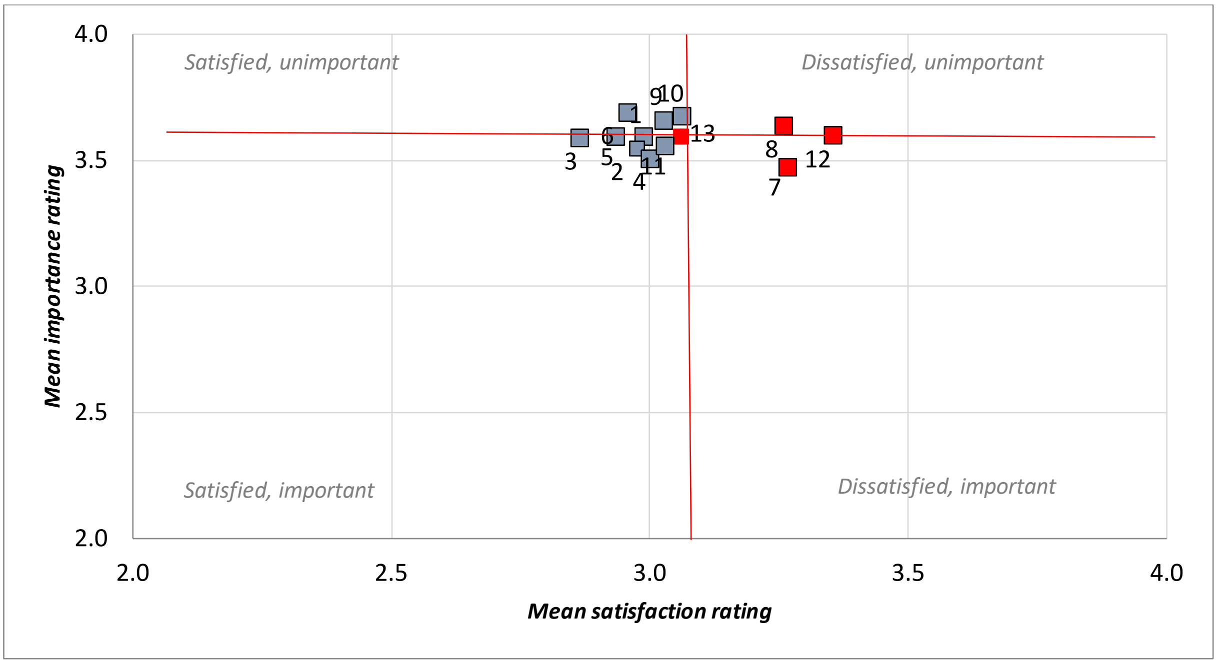
11 I can easily calculate the fee that I must pay for each trip I undertake.

12 The system protects my privacy.

13 Data centroid

Figure 6.4 | Mean satisfaction vs. importance rating of fuel levy

Analysis of the public's perception towards the DBRUC shows rating scores centered on the data centroid and scale median, indicating no perceived public opinion. This is not unexpected, as this system should be fairly new or unknown to them. What is apparent is that privacy is seen as the attribute that concerns most of the public, which is the opposite in the case of the fuel levy. Furthermore, the public is concerned with the trustworthiness of the system and about whether it will be accepted by all road users (Figure 6.5). These issues should be addressed and communicated as a priority to ensure a smooth transition to the new system with higher public acceptance.



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8 This system is trustworthy.

9 This system accurately determines the actual road-use cost incurred by the road user.

10 The fee charged per kilometre is transparent whereby I know which costs I incur and pay for.

11 I can easily calculate the fee that I must pay for each trip I undertake.

5 The system uses appropriate technology to calculate the cost that we must pay for using the road.
6 The system is inclusive: all road users pay for using the road.
7 This system is acceptable to all road users.
12 The system protects my privacy.
13 Data centroid

Figure 6.5 | Mean satisfaction vs. importance rating of DBRUC

Some differences were observed when comparing the above data with data gathered in 2013 by Indiana University. Although the survey data might not be a representative sample of the respective country nor comparable, it does provide some perspective on the difference in opinion of road users from around the world. When asked if the cost of a billing service facilitates the calculation of how much road users pay the government, 52% of the participants in the study agreed, while only 29% of participants in this survey. Only 40% of respondents in the USA study agreed when they were asked if a distance fee is an accurate way for the road users to charge for wearing and tearing on the streets, while only 24% in South Africa agreed.

Another study by the University of Nevada asked respondents (n=173) to rank distance-based fee components about personal importance. In terms of ease of use or simplicity, 70% of respondents ranked it as important while only 53% of respondents in this survey study did so. In terms of reliability or trustworthiness, 67% of respondents ranked it as important while only 52% of respondents in the current doctoral study did so. In terms of transparency, 54% of respondents ranked it as important while 55% of respondents in the current doctoral study did so. In terms of convenience or appropriateness, 70% of respondents ranked it as important while only 52% in the local survey. In terms of privacy, 57% of respondents ranked it as important while only 48% in South Africa.

6.4.1.4 Attitude

The survey sample indicated that less than half of respondents (46%) change their travel habits and patterns when the fuel levy is increased. The respondents suggested that faced with an increase in the fuel levy, they will travel less (34.3%) and avoid peak hour travel (18.3%).

In turn, 53% of respondents indicated that they think that having access to their road use cost by means of an invoice may motivate them to change their travel behaviour. The respondents would travel less (36.7%), avoid peak hour traffic (25%), and use alternative routes (26%), use public transport (22%) and carpool (18.8%).

6.4.1.5 Acceptance

When asked to use a scale of 1 to 10, where 10 implies very acceptable and 1 means completely unacceptable, 47.5% of the respondents rate the current system of a levy on every litre of fuel purchased at the pump as a method of raising funds for South Africa's road sector as relatively unacceptable, whereas 35.5% rate the fuel levy as relatively acceptable with a mean score of 4.8.

When asked to use a scale of 1 to 10, where 10 implies very acceptable and 1 implies completely unacceptable, 36.9% of participants rated the system of a DBRUC system as a technique of raising funds for South Africa's road industry as comparatively unacceptable, while 29.2% rated the DBRUC system as comparatively acceptable with a mean score of 4.8.

6.4.1.6 Favourability

The respondents indicated that their preferred method that the government should use to generate revenue for the funding of South Africa's roads is the conventional fuel levy followed by DBRUC. In addition, they favoured vehicle license fees followed by general taxes. However, they indicated an overwhelming disapproval in the use of toll roads.

If government only uses the current fuel levy system as a method to generate funding for roads it would satisfy only 30.7% of respondents. Adding a DBRUC system would increase the reach to 55% of respondents. This reach could be increased to 77.4% if general tax revenue were also used. Thus, 77.4% of all road users would be satisfied with the method used to fund South Africa's roads if only government implemented these three methods.

It seems that respondents 35 years and younger are more open to the notion or favourability towards DBRUC whereas respondents of 36 years or older are more in favour of the fuel levy.

6.5 Discussion and conclusion

Relying on the fuel levy as the primary funding source for roadway infrastructure is becoming less effective as the traditional means of transportation is negatively affected. A continuous increase in the fuel levy results in an increased demand for hybrid or fuel-efficient vehicles. This leads to the fuel levy securing less revenue from the fuel levy. The fuel levy will only become more unreliable in the future due to the growing variety of vehicle and fuel types. An alternative source of funding, such as the DBRUC, which will potentially replace the fuel levy in the near future, has to be taken into consideration by the government and the public. However, convincing the public that this type of change is required is easier said than done.

One of the reasons why an additional road-funding model, like the e-tolls, did not live up to its potential is due to a lack of public support and government's failure to understand public perception. Many initiatives tend to disregard the importance of public opinion. The purpose of this study was to determine what the opinion of the public is towards the current road user charge method of the fuel levy and implementation of a DBRUC. Understanding public opinion and level of acceptance can positively contribute to how policies should be implemented.

The following chapter evaluates the practicality of DBRUC by assessing to what extent DBRUC are operationally feasible and economically viable in South Africa.

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Appendix 6.A | Public opinion on road funding online survey questionnaire

Page 1

PUBLIC OPINION ON ROAD FUNDING

CONSENT TO PARTICIPATE IN RESEARCH

Dear Prospective Participant

The Department of Logistics at Stellenbosch University invites you to take part in a survey to assess the public opinion on road funding.

The purpose of the research is to assess the opinion of road users on how they pay for their use of the road and how this may change in future.

Please take some time to read the information presented here, which will explain the details of this project.

Your participation is entirely voluntary; That is to say, you are free to terminate your participation at any point in the survey. This will not affect you negatively in any way whatsoever.

The questionnaire will take approximately 10 to 15 minutes to complete and will contain a combination of questions covering your attitude and favourability towards two road use charging systems and your awareness, knowledge and perception of these systems. There are no right or wrong answers.

You will receive no compensation for participating in this research study.

No personal information will be requested or gathered during this survey.

RIGHTS OF RESEARCH PARTICIPANTS:

You have the right to decline answering any questions and you can exit the survey at any time without giving a reason. You are not waiving any legal claims and rights by agreeing to participate in this research study. If you have questions regarding your rights as a research participant, contact Mrs Maléne Fouché (mfouche@sun.ac.za; 021 808 4622) at the Division for Research Development.

Your information and your responses to the survey will be protected, because of your completing the questionnaire anonymously; Therefore, no information obtained during the study will be traceable to a specific participant. Only the researchers will have access to the questionnaires. The research data will be made available to the public, but no individual results will be disclosed. The researchers will publish only summarised results. All information collected will be included in a database for future research. If respondents agree to take part in future research, information such as names, addresses, contact details and vehicle information may also be stored in the database for future research. Again, no information obtained during future studies will be traceable to a specific participant.

If you have any questions or concerns about the research, please feel free to contact the principal investigator, Mr JA van Rensburg (javrens@sun.ac.za), or the research supervisor, Prof SC Krygsman (skrygsman@sun.ac.za), or both of them.

To save a copy of this text, save it according to the method used by your electronic device.

***I confirm that I have read and understood the information provided regarding the above-mentioned study.**

☐ Yes

***I agree to take part in this survey.**

☐ Yes

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Please provide us with some general information.

***How old are you?**

☐ 18-25 ☐ 35-55
☐ 26-35 ☐ 55 or older

***With what gender do you identify?**

☐ Male ☐ Other
☐ Female

***Do you own a vehicle? (This includes a motorcycle)**

☐ Yes ☐ No

***How often do you use the vehicle?**

☐ Everyday ☐ Infrequently
☐ Every other day

***In which province do you live?**

☐ Western Cape ☐ KwaZulu-Natal
☐ Eastern Cape ☐ Limpopo
☐ Northern Cape ☐ Mpumalanga

- ☐ Free State
- ☐ North West
- ☐ Gauteng
- ☐ Other

***In which municipal district of the Western Cape do you live?**

- ☐ City of Cape Town Metropolitan
- ☐ Eden District Municipality
- ☐ West Coast District Municipality
- ☐ Central Karoo District Municipality
- ☐ Cape Winelands District
- ☐ Other
- ☐ Overberg District Municipality

***In which district of the Eastern Cape do you live?**

- ☐ Cacadu District Municipality
- ☐ OR Tambo District Municipality
- ☐ Amatole District Municipality
- ☐ Alfred Nzo District Municipality
- ☐ Chris Hani Municipality
- ☐ Nelson Mandela Bay Metropolitan
- ☐ Ukhahlamba District Municipality
- ☐ Other

***In which district in the Northern Cape do you live?**

- ☐ Kgalagadi District Municipality
- ☐ Frances Baard District Municipality
- ☐ Namakwa District Municipality
- ☐ Other
- ☐ Pixley Ka Seme District Municipality
- ☐ Siyanda District Municipality

***In which municipal district of the Free State do you live?**

- ☐ Xhariep District Municipality
- ☐ Thabo Mofutsanyane District Municipality
- ☐ Motheo District Municipality
- ☐ Fezile Dabi District Municipality
- ☐ Lejweleputswa District Municipality

***In which municipal district of KwaZulu-Natal do you live?**

- ☐ Ugu District Municipality
- ☐ uMkhanyakude District Municipality
- ☐ uMgungundlovu District Municipality
- ☐ uThungulu District Municipality
- ☐ uThukela District Municipality
- ☐ iLembe District Municipality
- ☐ uMzinyathi District Municipality
- ☐ Sisonke Districk Municipality
- ☐ Amajuba District Municipality
- ☐ Ethekwini Municipality
- ☐ Zululand District Municipality

***In which municipal district of the North West do you live?**

- ☐ Bojanala District Municipality
- ☐ Dr Ruth Segomotsi District Municipality
- ☐ Ngaka Modiri Molema District Municipality
- ☐ Dr Kenneth Kaunda District Municipality

***In which municipal district of Gauteng do you live?**

- ☐ Sedibeng District Municipality
- ☐ Ekurhuleni Metropolitan Municipality

- ◻ Metsweding District Municipality
- ◻ City of Johannesburg Metropolitan Municipality
- ◻ West Rand District Municipality
- ◻ City of Tshwane Metropolitan Municipality

***In which municipal district of Mpumalanga do you live?**

- ◻ Gert Sibande District Municipality
- ◻ Ehlanzeni District Municipality
- ◻ Nkangala District Municipality

***In which municipal district of Limpopo do you live?**

- ☐ Mopani District Municipality
- ☐ Waterberg District Municipality
- ☐ Vhembe District Municipality
- ☐ Greater Sekhukhune District Municipality
- ☐ Capricorn District Municipality

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The following questions will assess your attitude towards the fuel levy and your awareness, knowledge and perception of it, as well as its acceptability to you. The fuel levy is the government's current method of generating income from road users.

***Are you aware that you are paying for your usage of the road network by means of a levy that is included in the price of fuel?**

◻ Yes	◻ No

***Are you aware that the fuel levy has been generating less income per vehicle per kilometre because vehicles have become more fuel-efficient and alternative propulsion systems, like electrical vehicles, are being developed?**

◻ Yes	◻ No

***Do you know what portion of the purchase price of a litre of fuel is earmarked as fuel levy currently?**

◻ Yes	◻ No

***Please state the amount, in cents per litre. (E.g. 210 cents)**

***Do you know how much fuel levy you pay <u>per kilometre</u> of road use?**

◻ Yes	◻ No

***Please state the amount, in cents per kilometre. (E.g. 10 cents)**

***Do you know what the fuel levy may be used for?**

◻ Yes	◻ No

***Please mark the programme(s) that the fuel levy should be used for in your opinion.**

◻ Roads	◻ All of the above
◻ Public transport	◻ None of the above
◻ General government expenditure	◻ I do not know

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The statements below describe various features of the fuel levy system. Firstly, please indicate whether you agree strongly, agree, disagree somewhat or disagree strongly with each statement. You may also indicate that you do not have an opinion on a certain statement i.e. option 3.

***To what extent do you <u>agree with</u> the following statements regarding the fuel levy?**

	Agree strongly 1	2	3	4	Disagree strongly 5
It is a simple method for charging road users for their use of the road.	○	○	○	○	○
It is an adequate method for ensuring a stable revenue stream from road users.	○	○	○	○	○
It is an equitable method whereby road users pay according to their use of the road.	○	○	○	○	○
It is an efficient method that makes road users aware of all the costs involved for the road system.	○	○	○	○	○
The method relies on appropriate technology to calculate the cost that we must pay for using the road.	○	○	○	○	○
The method is inclusive: all road users pay for using the road.	○	○	○	○	○
This method is acceptable to all road users.	○	○	○	○	○
This method is trustworthy.	○	○	○	○	○
This method accurately determines the actual road-use cost incurred by the road user.	○	○	○	○	○
The fee charged per litre is transparent; I know which costs I incur and pay for.	○	○	○	○	○
I can easily calculate the fee that I must pay for each trip I undertake.	○	○	○	○	○

The method protects my privacy.	○ ○ ○ ○ ○

The following statements describe various features of the fuel levy. Please indicate whether you think a specific feature of the fuel levy system is unimportant, relatively unimportant, important or very important. Here, too, you may also indicate that you do not have an opinion on a certain statement i.e. option 3.

***How <u>important</u> are the following statements regarding the fuel levy to you?**

	Unimportant 1 2 3 4 5 Very important
It is a simple method for charging road users for their use of the road.	○ ○ ○ ○ ○
It is an adequate method for ensuring a stable revenue stream from road users.	○ ○ ○ ○ ○
It is an equitable method whereby road users pay according to their use of the road.	○ ○ ○ ○ ○
It is an efficient method that makes road users aware of all the costs involved for the road system.	○ ○ ○ ○ ○
The method uses appropriate technology to calculate the cost that we must pay for using the road.	○ ○ ○ ○ ○
The method is inclusive: all road users pay for using the road.	○ ○ ○ ○ ○
This method is acceptable to all road users.	○ ○ ○ ○ ○
This method is trustworthy.	○ ○ ○ ○ ○
This method accurately determines the actual road-use cost incurred by the road user.	○ ○ ○ ○ ○
The fee charged per litre is transparent; I know which costs I incur and pay for.	○ ○ ○ ○ ○
I can easily calculate the fee that I must pay for each trip I undertake.	○ ○ ○ ○ ○
The method protects my privacy.	○ ○ ○ ○ ○

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***Do you change your travel habits and patterns when the fuel levy is increased? For example, do you**

travel less, or use a more fuel-efficient vehicle?

☐ **Yes**	☐ **No**

Please specify. (more than one answer allowed)

☐ **Travel less**	☐ **Use public transport**
☐ **Avoid peak hour travel**	☐ **Carpool**
☐ **Purchase fuel efficient vehicle**	☐ **Other**

***Using a scale of 1 to 10, where 10 means completely acceptable and 1 means completely unacceptable, how do you rate the current system of a levy on every litre of fuel purchased at the pump as a method of raising funds for our roads sector?**

Completely unacceptable			Neutral / Don't know				Completely acceptable		
☐ **1**	☐ **2**	☐ **3**	☐ **4**	☐ **5**	☐ **6**	☐ **7**	☐ **8**	☐ **9**	☐ **10**

Please feel free to explain why you scored the fuel levy system at this level.

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The following questions will assess your attitude towards a distance-based road user charge (DBRUC) system and your awareness, knowledge and perception of such system. In recent years, advancements in technology have led countries such as the USA and Australia as well as countries in Europe and Asia to implement a road-user charging system whereby road users pay for road usage according to the distance (kilometres) they travel. New technology, including global positioning systems (GPSs), have made accurate calculation of road usage possible. These programmes generate invoices for road users that indicate their actual road usage cost to be paid with reference to the vehicle used, road type, travel time and travel distance.

***Do you know what a distance based road user charge system entails and how it would work?**

☐ Yes	☐ No

***Are you aware that a distance based road user charge may be a fair payment system for road use that would also generate sufficient revenue for improvements to roads and related transport systems?**

☐ Yes	☐ No

***Do you know the exact amount that you need to pay per kilometre to recover the cost of you using the road network? Examples of costs incurred include road maintenance, congestion, environmental and road accidents**

◻ Yes	◻ No

***Please state the amount you think you <u>should</u> pay per kilometre. (E.g. 10 cents)**

***Do you know what the road use charge that you will pay by this system can be used for?**

◻ Yes	◻ No

***Please mark the appropriate programme(s) that the distance based road user charge system should fund.**

◻ Roads	◻ All of the above
◻ Public transport	◻ None of the above
◻ General government expenditure	

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The statements below describe various features of a distance based road user charge system. Firstly, please indicate whether you agree strongly, agree, disagree or disagree strongly with each statement. You may also indicate that you do not have an opinion on a certain statement i.e. option 3.

***To what extent do you <u>agree with</u> the following statements regarding a distance based road user charge system?**

	Agree strongly Disagree strongly 1 2 3 4 5
It is a simple system for charging road users for their use of the road.	○ ○ ○ ○ ○
It is an adequate system for ensuring a stable revenue stream from road users.	○ ○ ○ ○ ○
It is an equitable system whereby road users pay according to their use of the road.	○ ○ ○ ○ ○
It is an efficient system that makes road users aware of all the costs involved for the road system.	○ ○ ○ ○ ○
The system uses appropriate technology to calculate the cost that we must pay for using the road.	○ ○ ○ ○ ○
The system is inclusive: all road users pay for using the road.	○ ○ ○ ○ ○
This system is acceptable to all road users.	

	◯ ◯ ◯ ◯ ◯
This system is trustworthy.	◯ ◯ ◯ ◯ ◯
This system accurately determines the actual road-use cost incurred by the road user.	◯ ◯ ◯ ◯ ◯
The fee charged per kilometre is transparent; I know which costs I incur and pay for.	◯ ◯ ◯ ◯ ◯
I can easily calculate the fee that I must pay for each trip I undertake.	◯ ◯ ◯ ◯ ◯
The system protects my privacy.	◯ ◯ ◯ ◯ ◯

The statements below describe various features of a distance based road user charge system. Please indicate whether you think the relevant feature of the DBRUC system is unimportant, relatively unimportant, important or very important. Here, too, you may also indicate that you do not have an opinion on a certain statement i.e. option 3.

***How <u>important</u> are the following features of a distance based road user charge system to you?**

	Unimportant Very important 1 2 3 4 5
It is a simple system for charging road users for their use of the road.	◯ ◯ ◯ ◯ ◯
It is an adequate system for ensuring a stable revenue stream from road users.	◯ ◯ ◯ ◯ ◯
It is an equitable system whereby road users pay according to their use of the road.	◯ ◯ ◯ ◯ ◯
It is an efficient system that makes road users aware of all the costs involved for the road system.	◯ ◯ ◯ ◯ ◯
The system relies on appropriate technology to calculate the cost that we must pay for using the road.	◯ ◯ ◯ ◯ ◯
The system is inclusive: all road users pay for using the road.	◯ ◯ ◯ ◯ ◯
This system is acceptable to all road users.	◯ ◯ ◯ ◯ ◯
This system is trustworthy.	◯ ◯ ◯ ◯ ◯
This system accurately determines the actual road-use cost incurred by the road user.	◯ ◯ ◯ ◯ ◯

The fee charged per kilometre is transparent; I know which costs I incur and pay for.	○ ○ ○ ○ ○
I can easily calculate the fee that I must pay for each trip I undertake.	○ ○ ○ ○ ○
The system protects my privacy.	○ ○ ○ ○ ○

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***Do you think that having access to your road-use cost by means of an invoice may motivate you to change your travel behaviour?**

▯ **Yes**	▯ **No**

What changes do you think you will make? (more than one answer allowed)

▯ **Travel less**	▯ **Use public transport**
▯ **Avoid peak hour travel**	▯ **Carpool**
▯ **Use alternative routes**	▯ **Other**

***Using a scale of 1 to 10, where 10 means completely acceptable and 1 means completely unacceptable, how do you rate the idea of a distance based road user charge system for raising funds for our roads sector?**

Completely unacceptable			Neutral / Don't know				Completely acceptable		
▯ **1**	▯ **2**	▯ **3**	▯ **4**	▯ **5**	▯ **6**	▯ **7**	▯ **8**	▯ **9**	▯ **10**

Please feel free to explain why you scored the distance based road user charge system at this level.

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***What system would you prefer the government use to generate revenue for funding our roads? Please rank from 1 to 5, with 1 being your most preferred system.**

Fuel levy	
Distance-based road user charges	
Vehicle license fees	
Toll roads	
General taxes	

Please feel free to elaborate.

Page 10

***If you live within the area of City of Cape Town Metropolitan Municipality or Cape Winelands District Municipality, would you be willing to take part in a vehicle-tracking study to test a distance based road user charge system?**

☐ **Yes**	☐ **No**

***If "yes", please provide your e-mail address.**

Please follow this link to sign up for participation in the vehicle tracking study:

https://sunsurveys.sun.ac.za/DRiVE_signup.aspx

Please feel free to provide any further comments that you may have.

Thank you for taking the survey.

Chapter 7. Testing a voluntary distance-based road user charge in South Africa[1]

In Chapter 1, DBRUC was identified as a road cost recovery method, which could be implemented within the current South African road-funding framework to possibly secure funding from road users to meet the countries road expenditure requirements. Chapter 2 presented a comprehensive literature review to provide a clear understanding of DBRUC and where it fits into the road-funding environment, discussing the existing knowledge and research on this system and identifying areas or challenges that require further research. Chapter 3 showed that the current South African road funding framework is able to secure funding for roads to a great extent, but that the fuel levy is starting to show signs of decline when expressed per vehicle or km basis. Chapter 4 found that the emergence of disruptive transport technologies and societal trends will have a minor effect on most road cost recovery methods, but that fuel based systems are most at risk in experiencing declining revenues. Chapter 5 found that current road user charges does not fully comply with the user-pay principle and that a charge structure based on short-run MSC might be a favourable avenue to generate additional revenue for the road sector. Chapter 6 found that road users are seemingly unaware of the cost of their road usage, not fully comprehending road charges that they pay nor what these funds are used for. Furthermore DBRUC is seen as an acceptable road cost recovery in addition to the fuel levy. Chapter 7 aims to address research question 5, which evaluates the practicality of DBRUC by assessing to what extent DBRUC are operationally feasible and economically viable in South Africa.

The chapter starts by introducing the topic of testing a voluntary DBRUC in South Africa while explaining its relevance to the study, stating the aim and objectives and outlining the main points of the research. Thereafter the key technical components required to implement a DBRUC system is presented. It continues by providing a description of the research methodology employed to address the chapter's aim which includes a vehicle tracking study and cost allocation analysis, outlining the objective of each method, describing the method design and limitation. This is followed by presenting the research results firstly from generating a DBRUC invoice in South Africa through a vehicle tracking study reflecting on the vehicle

[1] Sections of this chapter are contained in articles already published in peer-reviewed conference proceedings (Van Rensburg & Krygsman, 2016, 2018).

tracking data output and the data analysis and invoice compilation. This is done by tracking a road user for a period of one week with the aid of an on-board vehicle-tracking device, processing the data and applying a flat rate per km to calculate the road user's cost owed for using the road network. Secondly, from calculating the revenue potential of a DBRUC in South Africa through a cost allocation analysis investigating the revenue from applying the fuel levy fee, revenue from applying the OReGO model, revenue from applying a variable short-run MSC-based congestion charge, revenue from applying the Freeman model and then comparing the different charging approaches' revenue. This is done by tracking 18 road users for a period of one month with the aid of on-board vehicle tracking devices, processing the data and applying various rates per km as calculated through four cost allocation methods to calculate the road users' cost owned for using the road network. The chapter concludes with a discussion on future research required to develop a DBRUC system in South Africa.

7.1 Introduction

While technological developments have a negative effect on the extent to which traditional road cost recovery methods can generate sufficient revenue, they have opened up an avenue for the implementation of new methods. These methods can even solve some of the issues with conventional road cost recovery methods. One such method includes DBRUC systems charging road users based on actual road use and are differentiated by time of day and type of vehicle. This system is considered an excellent solution to the fuel levy issues as it is not affected by technological and social trends and is not dependent on fuel sales. It can also be a progressive tax where fuel levies typically penalise poorer road users using older, less fuel-efficient vehicles. Road user behaviour is influenced by road user costs, among others, and a change in the user charge, such as a higher road user charge during peak hour travel on urban roads, may therefore induce a change in behaviour.

Although a DBRUC is theoretically sound, full-scale implementation of the system has been hampered by various factors including system costs, ethical and privacy concerns, and the technical requirements to make such a system tamper-proof and mandatory. A number of pilot projects are being undertaken to solve some of these issues, and experiments and programmes in progress in the USA, the EU and Asia illustrate the system's practicality. The system already works in some areas of the world for heavy goods vehicles.

Therefore, this chapter aims to evaluate the practicality of DBRUC by assessing to what extent DBRUC are operationally feasible and economically viable in South Africa. This will be done by i) generating a DBRUC invoice in South Africa through a vehicle tracking study, and ii) calculating the revenue potential of a DBRUC system in South Africa through a cost allocation analysis.

7.2 Literature review

The literature review briefly discusses the key technical components of a DBRUC system.

7.2.1 Key technical components of DBRUC

Findings from international studies and pilot projects indicate that there may be many configurations for a DBRUC system, but 11 main technical components must be incorporated. These components include:

1. The purpose of the implementation;
2. Which vehicles and users to be charged;
3. Technological devices for measuring km travelled;
4. Communication of the vehicle travel data;
5. The road type to be charged;
6. The time of day that will be charged;
7. How much to charge;
8. Invoice billing;
9. Enforcement of the system;
10. Protection of privacy; and
11. Value-added services.

These technical components are briefly discussed in the following sections. Firstly, a DBRUC system can have numerous purposes that warrant its implementation. It can possibly decrease congestion, excessive road wear and harmful emissions and secure funds for investment in transport infrastructure (Coyle, Robinson, Zhao, Munnich & Lari, 2011; Sorensen, Ecola & Wachs, 2012). A DBRUC system can promote congestion pricing across all crowded sections of the road network by promoting a fee structure based on time of day and travel location. In the USA, the Puget Sound Regional Council carried out pilot projects to examine this system and found that it was efficient in decreasing traffic, particularly during peak hours (Puget Sound

Regional Council, 2008). A neighbouring state, Minnesota, is exploring a similar system in its continuing DBRUC projects (Buxbaum, 2006).

Furthermore, heavy commercial vehicles cause considerably more road damage than lighter passenger vehicles. A DBRUC system for trucks can differ based on axle weight to assist reducing excessive road wear. This will encourage truckers to adopt trailer configurations aimed at reducing axle loads and traveling on highly engineered roads or primary arteries where possible. Charges can be set higher for vehicles that are less eco-friendly and lower for vehicles that are eco-friendlier. This will create an incentive for drivers to select models with lower emissions when purchasing a new vehicle. This approach has been used for a truck toll in Germany, where the most eco-friendly vehicles pay almost 50% less per km than the most non-eco-friendly vehicles (Forkenbrock & Kuhl, 2002).

Secondly, vehicle characteristics are attributes that can be used to distinguish the fundamental pricing structure in a DBRUC system (Hatcher, Bunch, Hardy, McGurrin & Hardesty, 2009). The revenue model will promote a progressive tax system by charging vehicles differently by type and weight, number of axles, vehicle emissions, vehicle energy efficiency and vehicle occupancy.

Thirdly, it is possible to use numerous technologies to measure vehicle km travelled. Periodic odometer checks with annual registration can be used to determine km fees owed (Sorensen *et al.*, 2012; Sorensen, Ecola, Wachs, Donath, Munnich & Serian, 2009). Odometer measurements can also be automatically reported where drivers report their present km annually as part of the annual registration process (Coyle *et al.*, 2011; Sorensen *et al.*, 2009).

A vehicle can also be fitted with a straightforward on-board device that can be attached to the on-board diagnostic port capable of electronically calculating km of travel. This system will include electronic communication to convey km information without regular inspections of vehicles (Coyle *et al.*, 2011; Sorensen *et al.*, 2012). It is also possible to equip vehicles with automated vehicle identification systems featuring technology tags for radio frequency identification. Through dedicated short-range communication technology, these will interact with gantries set up along the most highly travelled road network sections (Coyle *et al.*, 2011). Alternatively systems can use an electronic sticker-based system called e-Vignette. Toll stickers are connected to vehicles denoting travelling on particular roadways having paid the suitable usage fee. Furthermore, the on-board device will also be fitted with cellular communications, which will enable the place of travel to be determined. This setup makes it possible to differ prices by vehicle features, national or provincial jurisdiction or by smaller geographic area (Coyle *et al.*, 2011; Sorensen *et al.*, 2012). A more sophisticated on-board device option will include a GPS receiver along with wireless communications, enabling the particular path, and possibly even the particular route, of travel to be determined.

Rather than relying on expensive in-vehicle equipment, km can be measured with a smartphone application, which provides GPS and cellular communications for measuring and reporting km data (Sorensen *et al.*, 2012). Furthermore, fuel consumption can serve as the basis for estimating travel distance. It is possible to equip all vehicles with some type of automated vehicle identification device. When a vehicle visits a fuel station to purchase fuel, electronic readers installed at the pump will detect the vehicle ID and use this information to determine the vehicle's fuel-economy rating based on the make and model. It is then possible to estimate the anticipated km travelled based on the quantity of fuel bought. The corresponding charge can then be added to the fuel purchase price, while the fuel levy will be subtracted (Coyle *et al.*, 2011).

Fourthly, the back-end system has been using three separate techniques to communicate travel behaviour and billing information. These include dedicated short-range communications (DSRC), Global Systems for Mobile (GSM) and chip cards. Dedicated short-range communications rely on short-range microwave communications between vehicles and roadside receivers and transponders. This technology is frequently used to determine when vehicles enter or exit certain sections of roads or geographical regions. Global System for Mobile is an alternative to DSRC, which can be used to communicate travel data or billing data. Although typically more costly than DSRC, GSM does not require the installation of roadside communications devices and, furthermore, it permits real-time communications. A chip card is a small, credit card-sized device with an embedded computer chip or memory module. The most common use of chip cards within road pricing applications is to store and transfer billing data from the on-board unit to a card reader that can relay the information to the collection's agency. Card readers might be set up at fuelling stations, or alternatively they can be attached to a home computer with Internet access (Sorensen & Taylor, 2005).

Fifthly, there are many cases where a location-based charge is desirable for general demand management as in a central business district. Location-based charging implements a charged based on where a vehicle travels (Hatcher *et al.*, 2009).

Sixthly, there is a varying rate depending on the time of day. Time-of-day charging adds an additional layer to the DBRUC by fluctuating the fee rate based upon the time of day a vehicle is travelling on the road infrastructure. This additional layer enables a transportation agency to better manage travel demand by providing a financial incentive for someone to travel during lower-demand periods.

Seventhly, there is the rate to be charged per km. The Oregon DBRUC model assessed a flat rate of $0.17 per km for all travel in Oregon, while the off-peak paid a lower rate of $0.06 per km for most travel, but $1.40 per km when traveling in congested areas during peak hours. In the Puget Sound Regional Council Study, depending on the time and route, the km rate ranged from $0 to $5.62 per km (Sorensen *et al.*, 2012).

Eighthly, models for reporting km and collecting payment must be provided by the system. Relevant issues include the payment frequency and method along with suitable public- and private-sector roles in the collection of payments and management of accounts. Payment options might include automated debit accounts, monthly billing, annual payment with registration, or even payment with fuel purchases.

Ninthly, the system must include effective strategies for preventing or detecting efforts to evade payment fees. Although numerous strategies have been proposed to prevent toll evasion, they can generally be grouped into two categories: i) designing the on-board unit in such a manner as to prevent tampering or disabling and ii) observing the vehicle from fixed or mobile check points to ensure that charges are being recorded.

Tenthly, a DBRUC system must protect the privacy and security of personal travel and billing data. Four approaches to privacy are possible: relying on metering options that provide no information about the location of travel, relying on a trusted third party to protect and secure private data, designing the technology with built-in privacy safeguards, and establishing privacy legislation that clearly distinguishes between permissible and impermissible uses of personal travel data. To strengthen privacy protection, several of these can be applied jointly.

Finally, a DBRUC system must include value-added services. In-vehicle metering equipment can be configured to allow for automated payment of parking charges, eliminating the requirement to pay at parking meters. Drivers can pay for the actual time that they occupied the space. On toll roads, in-vehicle metering equipment can support automated toll payments, eliminating the requirement to stop at the tollbooth and have cash. The in-vehicle equipment can share many features associated with personal navigation devices, such as real-time routing assistance based on current traffic conditions and identification of nearby points of interest. In-vehicle devices can provide satellite radio or serve as a Wi-Fi node for passengers. This can lead to a broad range of in-vehicle wireless applications, such as parking location and reservation services.

7.3 Research methodology

In order to evaluate the practicality of DBRUC by assessing to what extent DBRUC is operationally feasible and economically viable within South Africa, a vehicle tracking study and cost allocation analysis were performed. The research methodology briefly provides an overview of each technique used, where after these techniques are discussed in terms of its objectives, the method employed as well as the limitations of the method.

7.3.1 Vehicle tracking study

A vehicle tracking system combines the use of automotive vehicle location in individual vehicles with software that collects these fleet data for a comprehensive picture of vehicle locations. Modern vehicle tracking systems commonly use GPS technology for locating the vehicle, but other type of automotive vehicle location technology can also be used. Vehicle information can be viewed on electronic maps via the internet or specialised software. Urban public transport authorities are an increasingly common user of vehicle tracking systems, particularly in large cities.

7.3.1.1 Objective of method

The vehicle tracking study intents to generate a DBRUC invoice in South Africa. The method set out to prove that a vehicle can be tracked accurately given the available technology in South Africa and thereafter produce a sort of invoice depicting the cost the vehicle incurred during the period of travel.

7.3.1.2 Description of method

A DBRUC system configuration was tested using one vehicle in a small-scale proof-of-concept study in November 2015, comprising selected key technical components. The configuration was designed in order to charge all self-propelled vehicles for the infrastructure cost they incurred on the road system. A removable GPS unit with GSM technology was fitted to the vehicle and tracking was undertaken for a period of one week collecting vehicle movement data comprising x- and y-coordinate pairs on all roads every 30 seconds throughout the day. The use of the system was enforced by assessing the vehicle's odometer reading throughout the tracking period. The vehicle movement data was sent to a third-party vehicle tracking company's server and reported via their secure web-based interface. A back-end system extracted various data sets from the web-based interface in order to compile a billing invoice to be forwarded to the vehicle owner, depicting the road use charge owed. A value-added service was also provided by showing information related to the vehicle movement, which might facilitate a change in travel behaviour.

The road use charge for the tracked vehicle was calculated at R0.21 per km by means of dividing the estimated annual maintenance, administration, street cleansing, street lighting and capital costs incurred by the vehicle class to which it belongs by the vehicle class's estimated annual km travelled (Freeman, 1982). The calculation assumed a total infrastructure expenditure of R54.6 billion[2] for all vehicle classes and then allocated the cost to each vehicle class in terms of the above-mentioned cost components. Added to this calculated road use charge is an operating cost of 5% for the DBRUC system that will be implemented resulting in a charge of R0.23 per km.

The invoice was compiled with a similar look and feel to reflect the municipal account invoice of the City of Cape Town. The DBRUC owed was calculated by multiplying the DBRUC rate per km by the number of km travelled. The invoice also incorporated a rebate for the fuel levy already paid. The fuel levy rebate was calculated by multiplying the average fuel consumption per km of the vehicle by the number of km travelled and the fuel levy rate. The fuel levy rebate amount was then subtracted from the total DBRUC owed by the participant to show the additional road user charge owed. Additional information related to travel behaviour and vehicle operating cost was included as a value-added service. The vehicle operating cost was calculated by means of the AA rates for vehicle usage.

[2] Estimated revenue generated through the fuel levy in 2015

7.3.1.3 Method limitation

A limitation of the study was the small sample size and the short period of tracking. It was decided to only track one vehicle. This would be enough to prove in principle that a vehicle can be tracked and a fee can be charged per km of travel. Although it is stated that all vehicles after 1996 can be equipped with an OBD-II device, it was found that some vehicles manufactured after 1996 cannot be equipped with this device as connector points in some devices and vehicles are not compatible.

7.3.2 Cost allocation analysis

Cost allocation is the process of identifying, aggregating and assigning costs to a particular service or product. This service or product can be any activity or item for which separate cost measurement is required. The purpose hereof is to justify costs for pricing or reimbursement.

7.3.2.1 Objective of method

The cost allocation analysis intents to calculate the revenue potential of a DBRUC system in South Africa. The cost allocation study had two objectives. Firstly, it aimed to build on the proof-of-concept study where only one vehicle was tracked and to grow the vehicle tracking study to track numerous different vehicles of road users with different levels and magnitude of travel behaviour. Secondly, it aimed to assess different costing methods, incorporating different values of cost for which road users are responsible in terms of the revenue-generating capability per vehicle.

7.3.2.2 Description of method

In May 2017, an invitation to take part in a voluntarily road user charging study was circulated to staff of a large employer. The study was undertaken in the Cape Winelands District Municipality and the City of Cape Town, Western Cape. Eighteen participants were selected to take part in this study. A screening process followed to verify that they used their vehicles on a regular basis, that they were the registered owners of the vehicles, that the vehicles were manufactured after 1996 and that they were willing to provide consent for their daily vehicle activity to be recorded and analysed.

Arrangements were made with each participant to install the OBD-ii tracking device at a time and place of their convenience. Installation took less than 5 minutes, which included a general explanation to the participants of how the device worked and an opportunity for any questions that the participants may have had. Self-installation, as is done in the USA and the EU, is possible, which will allow the units to be mailed to reach participants. Participants would then just have to confirm installation and device signal through a communication channel.

The voluntary vehicle tracking study commenced at the beginning of June 2017 and continued for a four-week period. No active participation was required from the participants during this period other than keeping the units plugged in.

Vehicle tracking data for each vehicle was downloaded from the third party's web-based interface on a weekly basis. The tracking data, recorded every 10 seconds, consisted of information about vehicle travel behaviour, including speed, the time and the vehicle's location. Data analytics was used to determine the vehicle's travel distance between each recorded point, whether the vehicle travelled in the daily peak period (07:00 to 08:00 and 17:00 to 18:00) and the type of road travelled on (freeway, main road and other).

Road use cost was then modelled for each participant based on different pricing methodologies. Firstly, the conventional fuel levy charge as set by the South African government in 2017 for petrol and diesel was considered. Secondly, OReGO's road user charge model which is merely a conversion of the fuel levy to a distance-based charge based on average vehicle fuel efficiency (State of Oregon, 2017) was considered. This was done by assessing all available vehicle models in South Africa indicating an average fuel consumption value of 6.9 litres per 100 km. This equates to an average of 14.5 km per litre of fuel used whereafter the fuel levy charge was calculated by dividing this by the km travelled per litre of fuel sold. Thirdly, the average cost for each vehicle class based on the vehicle class's combined distance travelled per annum to cover the road expenditure required for the year was determined (Department of Logistics, 2017; Freeman, 1982). This was calculated by determining the operational, regulation cost, the infrastructure capital and maintenance cost per vehicle class based on their vehicle population in the country, and average distance travelled per annum of a total road expenditure requirement of R117 billion for 2017.

Table 7.1 | Alternative road user charge calculation approaches and values (2017)

(Sources: Freeman, 1982; Department of Energy, 2017)

	Current South African fuel levy: general fuel levy (2017)		Current South African fuel levy: combined fuel levies (2017)		OReGO model*		Freeman model**
	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	
	(R/l)	(R/l)	(R/l)	(R/l)	(R/km)	(R/km)	(R/km)
Cars	R3.15	R3.00	R4.92	R4.67	R0.33	R0.32	R0.58
LDV's/Bakkies	R3.15	R3.00	R4.92	R4.67	R0.33	R0.32	R0.58
Minibuses	R3.15	R3.00	R4.92	R4.67	R0.33	R0.32	R0.58
Buses	R3.15	R3.00	R4.92	R4.67	R0.33	R0.32	R1.25
Trucks	R3.15	R3.00	R4.92	R4.67	R0.33	R0.32	R1.46
Motorcycles	R3.15	R3.00	R4.92	R4.67	R0.33	R0.32	R0.50
Other	R3.15	R3.00	R4.92	R4.67	R0.33	R0.32	R1.13

*Based on an average vehicle fuel efficiency of 6.9l/100km

-- Based on South Africa's road expenditure of R117 billion (2017)

Lastly, economists typically consider an efficient price of a resource, in this case roads, as the MSC. Social costs include the costs to society in addition to the private costs of road use. Marginal refers to the additional costs, or the incremental unit, that are causally related to the road user (Delucchi, 2000; Kahn, 1970). The components of MSC typically include the marginal infrastructure cost, congestion cost, accident cost and environmental cost and operating subsidies. It is notoriously difficult to estimate MSC and good quality data on road maintenance and management costs, the vehicle fleet (size and composition), vehicle emissions and the costs of congestion is not readily available in South Africa. Cost allocation to specific vehicle types is therefore quite coarse (Korzhenevych, Dehnen, Brocker, Holtkamp, Meier, Gibson, Varma & Cox, 2014). It is not possible, within the scope of this study, to determine MSC estimates for South Africa. Estimates of MSC have been determined in the EU and Table 5.1 illustrates short-run MSC congestion charges converted to South African rand per km based on PPP (Chapter 5).

7.3.2.3 Method limitation

A limitation of this study was the calculation of the MSC. The calculation was not entirely accurate due to unavailability of data.

7.4 Research results

The results section firstly presents the findings from performing the vehicle tracking study where a DBRUC invoice in South Africa was generated. This include a discussion of i) the vehicle tracking data output and ii) the data analysis and invoice compilation. Secondly, it presents the findings from performing the cost allocation analysis where the revenue potential of a DBRUC system in South Africa was calculated. Herewith the revenue from applying the i) fuel levy, ii) the OReGO model, iii) a variable short-run marginal social congestion cost based road user charge, iv) the Freeman model and v) the comparison of the charging approaches' revenue are discussed.

7.4.1 Generating a DBRUC invoice in South Africa

A DBRUC system configuration (see Figure 7.1) was tested using one vehicle, in a small-scale proof-of-concept study in November 2015, comprising selected key technical components.

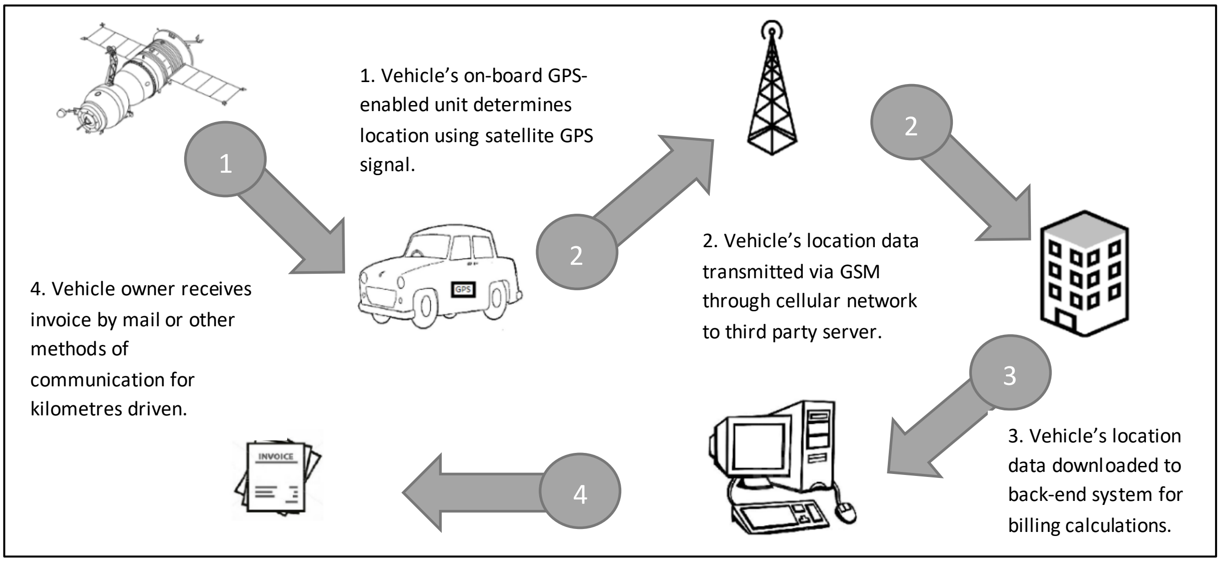

Figure 7.1 I Distance-based road user charge configuration
(Source: Van Rensburg and Krygsman, 2016)

The invoice was compiled with a similar look and feel the municipal account invoice of the City of Cape Town (Figure 7.2). The DBRUC owed was calculated by multiplying the DBRUC rate per km by the number of km travelled. The invoice also incorporated a rebate for the fuel levy already paid. The fuel levy rebate was calculated by multiplying the average fuel consumption per km of the vehicle by the number of km travelled and the fuel levy rate. The fuel levy rebate amount was then subtracted from the total DBRUC owed by the participant to show the additional road user charge owed. Additional information related to travel behaviour and vehicle-operating cost was included as a value-added service. The vehicle operating cost was calculated by means of the AA rates for vehicle usage.
Figure 7.2 shows that the vehicle was operated for almost 10 hours, driving 332.64 km while undertaking 31 trips at an average speed of 37 km per hour. Distance travelled data obtained

from the odometer readings was compared to the distance calculated from the x- and y-coordinate pairs. The deviation was less than 1% (2 km).

UNIVERSITEIT STELLENBOSCH

Stellenbosch University
Private bag X1
Matieland
7602

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Account number	*000001*
Reference number	*000001*

Road User Charge Invoice

Tel: '+27 21 808 2879
Fax: '+27 21 808 3406
E-mail: javrens@sun.ac.za
Correspondence: Researcher
Private bag X1
Matieland, 7602
Web address: www.sun.ac.za

Name	Participant 1
Address	Bosman Street
Suburb	Stellenbosch
Postal code	Private Bag X1, Matieland 7602, South Africa

Account summary as at	*2015-11-30*	**Due date**	*2015-12-28*
For vehicle:	*CY 123456*		
Previous account balance			*R* -
Less payments			*R* -
(a)	*R* -		*R* -
Current amount due (b)	*2015-12-28*		*R* 31,03
	Total (a) + (b)		*R* 31,03
Total (a) + (b) above	*R* 31,03		
Total liability	*R* 31,03		

Travelling information

Distance travelled (km)	332,64	Amount of trips	31
Time spend travelling	9:39:56		
Ave speed (km/h)	37,36		

Travelling cost

Vehicle running cost	R 359,25	Fuel cost	R 222,55
Vehicle fixed cost	R 934,71		
Total vehicle cost	R 1 293,96		

Please note:
(1) Billed for use of National, Provinsial and Municipal Roads
(2) Billed according to distance travelled
(3) Billed according to time of day travelled
(4) Interest will be charged on all amounts still outstanding after due date
(5) You may not withhold payment, even if you have submitted a query concerning this payment

Pay points: Stellenbosch University cash offices or the vendors below

ABSA Bank	PayCity	Checkers	SPAR
Shoprite	WOOLWORTHS	Pick n pay	Post office

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Account details as at	*2015-11-30*	**Account number**	*000001*

Charge	**- Period**	***2015-11-11* to**		***2015-11-19***	***8***	
332,6365996	km	x	*0,231*			*R* 76,84
Fuel levy rebate	**- Period**	***2015-11-11* to**		***2015-11-19***	***8***	
17,96237638	litres*	x	*2,55*			*R* -45,80
						R 31,03

* Kia Rio, 2015 model, uses on average 5,4 litres per 100 kilometres = 0,054 litre per kilometre
0,054 litre x 332,6366 kilometres = 17,9623764 litres

Current account: Total due - *R* 31,03

Figure 7.2 | Distance-based road user charge invoice

(Sources: Own calculations; Automobile Association, 2015; City of Cape Town, 2015)

The vehicle used R222.55 worth of fuel, while accumulating a vehicle operating cost of R359.25 over this period. The total DBRUC was calculated at R76.84 for the 332.64 km driven at a set rate of R0.23 per km. The fuel levy already paid was calculated at R45.80 for using 17.96 litres of fuel at a fuel levy rate of R2.55 per litre (Engen, 2016). This resulted in the participant owing an additional amount of R31.03 for road use.

7.4.2 Calculating the revenue potential of a DBRUC in South Africa

The results of the experiment are presented in Table 7.3. The participants' distance driven for the period varied substantially, mainly due to different distances between home and work, the commute trip, and the demands of their employment. Vehicle composition also varied from fuel-efficient vehicles to fuel-inefficient SUVs. The conventional fuel levy, column 3, which at the time of the pilot represented R4.92 and R4.67 per litre of petrol and diesel respectively, delivered a revenue of R7 722.03. This was calculated by the combined fuel levies, be that petrol or diesel used by the specific vehicle, multiplied by the amount of fuel used based on distance travelled and the vehicle's fuel efficiency. The OReGO model, column 2, converts the fuel levy into a km rate based on an average fuel economy of 6.9l/100 km. This is multiplied by each participant's distance travelled. Short-run MSC, column 4, which includes marginal infrastructure, emission, congestion and accident costs, delivered the most revenue of the various pricing techniques. As most travelling takes place in the congested urban areas and peak period, the congestion costs that comprise a significant element of MSC are responsible for this. Freeman's approach, column 5, uses an average cost per km and is derived from the estimated annual expenditure of R117 billion on the road sector (2017), allocated to different vehicles types and multiplied by the distance. The approached delivered a revenue of R13 497.47.

Table 7.2 l Envisaged revenue to be collected by different charging approaches

Participant #	Km driven	1 Fuel Levy	2 OReGO' model	3 Short-run MSC congestion	4 Freeman's model
Participant 1	1 019.20	R575.93	R404.58	R2 263.63	R587.20
Participant 2	1 156.10	R458.92	R458.92	R1 063.85	R666.07
Participant 3	1 132.43	R451.60	R473.90	R501.60	R652.44
Participant 4	1 202.55	R367.07	R503.24	R2 934.90	R692.84
Participant 5	3 013.53	R786.34	R1 261.10	R4 810.60	R1 736.21
Participant 6	1 036.22	R336.71	R433.64	R2 052.51	R597.01
Participant 7	661.55	R373.83	R262.61	R393.87	R381.15
Participant 8	812.92	R248.14	R340.19	R393.87	R468.35
Participant 9	917.65	R244.27	R364.27	R3153.67	R528.69
Participant 10	786.71	R304.94	R312.29	R2 680.14	R453.25
Participant 11	2 460.50	R702.60	R1 029.67	R1 914.68	R1 417.59
Participant 12	423.20	R239.14	R167.99	R1 123.07	R243.82
Participant 13	2 222.13	R809.58	R929.92	R2 989.43	R1 280.26
Participant 14	789.11	R240.87	R330.23	R534.87	R454.64
Participant 15	1 195.77	R365.00	R500.41	R535.96	R688.93
Participant 16	1 005.92	R292.20	R420.96	R2 431.24	R579.55
Participant 17	2 064.79	R548.94	R864.07	R5 267.37	R1 189.60
Participant 18	1 527.21	R375.95	R639.11	R441.25	R879.88
Total	23 427.49	R7 722.03	R9 697.10	R35 486.52	R13 497.47

The existing fuel levy, column 2, delivered the least revenue from the four approaches. This is in part due to most vehicles being fuel-efficient and the levy not incorporating actual road use cost incurred. By applying OReGO's model, which is essentially the fuel levy per km based on an average vehicle fuel efficiency, a 26% increase in revenue can be generated compared to the fuel levy. This illustrates the impact of fuel efficiency. Freeman's approach in turn delivers close to double the revenue, because it factors in all cost required to fund the road sector for the specific year and not just a historic value adjusted to inflation and budgetary requirements. The MSC charging method is indeed able to generate more revenue from road users than the other approaches (increase of 360% over the fuel levy). This reflects the distinctive characteristics of the MSC (short-run) curve at high levels of output (demand). Congestion costs increase significantly in urban areas in peak times, which leads to the road user charges.

Participant 1 is somewhat of an anomaly and after applying the OReGO method; the driver would have paid less road user charges compared with the fuel levy. This is because the participant's vehicle is not as fuel-efficient as some of the other vehicles and above the average vehicle fuel efficiency of 6.9l/100km and thus benefit from the average fuel efficiency assumption. Internalising their externalities through the MSC charge shows a fee four times more than the current fuel levy payment for the month.

This is in contrast with participant 18 who drove more km but used a more fuel-efficient vehicle, compared to the average fuel efficiency, thus paying less. As a result, the OReGO method would see the participant paying almost double. This indicates a possible flaw of the OReGO method, which at a flat fee will secure more revenue from owners of fuel-efficient vehicles and less from owners of inefficient vehicles but at the expense of motivating behavioural change to more environmentally friendly vehicles. Participant 18 would still pay more according to Freeman's model but in terms of MSC would not see such a huge increase in cost as the other participants. This is due to the participant driving in a rural region for the month using highways where possible and mostly in the off-peak period (see Table 7.3).

Accordingly, older, less fuel-efficient vehicles will benefit from a more equitable OReGO model approach, and new, more fuel-efficient vehicles will benefit more from the conventional fuel levy.

7.5 Discussion and conclusion

It was shown that DBRUC is a viable alternative that may not be influenced by technological and societal trends nor is it dependant on fuel sales, as the case with other road cost recovery methods, as it directly charge road use by monitoring the actual time and distance of vehicle travel and then charging appropriately for that use. Furthermore, the system could equip vehicles to allow for future initiatives, such as congestion pricing and increased efficiency of the toll collection process (Fichtner & Riggleman, 2007).

A DBRUC system was found to have many configurations comprising various key technical components that should be taken into consideration. These components include the purpose of the implementation, which vehicles and users to be charged, technological devices for measuring km travelled, communication of the vehicle travel data, the type of road to be charged, the time of day that will be charged, how much should be charged, invoice billing, enforcement of the system, protection of privacy and value-added services.

A vehicle tracking experiment has shown that a suggested configuration of the system is operationally feasible on a small scale in South Africa. A removable on-board GPS unit with GSM technology was acquired from a third-party tracking company. Installation was quick and the service was easy to use. Information pertaining to the vehicle's movement was secure and only available to the participant and researcher via a web-based interface. Vehicle travel data was readily available in the correct format for analysis and a road user invoice can be constructed with ease, charging the vehicle owner for the distance travelled at a set rate per km.

Furthermore, a comparison was made between four road pricing methodologies that included the current fuel levy used in South Africa, the fee structure used in OReGO, USA, a simplified average costs model devised for South Africa in 1980 and an approximate marginal social cost approach. The results show that the conventional fuel levy delivered the smallest revenue while the MSC approach delivered the biggest revenue. This can be attributed to the congestion cost element associated with the MSC due to the peak time and urban focus of the majority of trips. The results further show that a cost allocation approach is key in ensuring the effective cost recovery of all road costs incurred. A fee structure based on the fuel levy is not effective and is subject to the fuel efficiency of the vehicle being operated. The best option is to use a MSC fare structure that incorporates infrastructure, accident, and environment and congestion costs. Distance-based road user charges, although incurring more implementation and operating cost than the current fuel levy system, is easy to use and understand. It could provide greater funding security to government and information regarding cost to infrastructure providers and users to make informed decisions.

A key system requirement is that implementation cost should be acceptable from the perspective of the implementing authority and the users. The various models currently employed to generate revenue from road users in South Africa all have different collection costs. Firstly, fuel levies, including the general fuel levy and the Road Accident Fund Levy, generate 70% of the total direct road user revenue collected per annum at a very low collection cost, i.e. less than 1% (both locally and internationally) (Bahl, 1992; Balducci, Shao, Amos & Rufolo, 2011; Department of Logistics, 2017; Duvenage, 2015). Secondly, toll roads generate a further 10% of direct road user revenue with a collection cost of around 30% (Duvenage, 2015; OUTA, 2018). Thirdly, models that stem from regulation, which include the issuing of vehicle licence fees, fines and permits, contribute 18% to the total direct road user revenue while collection costs can amount to 50% (National Treasury, 2014). Lastly, CO_2 emission tax contributes 2% to direct road user revenue with a collection cost of 1% (SARS, 2016). International experience suggests that the administrative and enforcement cost of collecting

DBRUC would be around 5% to 13% of revenue collected (Balducci *et al.*, 2011; Kirk & Levinson, 2016). The advancement of technology used by DBRUC would further reduce the collection cost and several other benefits may offset this higher cost, including user information. A back-of-the-envelope calculation using the experience gained through the DRiVE initiative is showing a collection ratio of 9%. Further work will refine this cost estimate.

The South African government, on all three levels, and road users should be aware of the exact cost that are required to provide, maintain and expand South Africa's roads to ensure a functioning road network. This should further be delegated to the micro level where each vehicle owner knows their exact cost imposed on the road network, not only in terms of road wear or required capacity, but also in terms of external costs pertaining to accidents, environmental pollution from operating a vehicle and congestion, through an exact user charge. The success of a DBRUC system includes the participation of all stakeholders through the advent of small-scale voluntary experiments growing in size each year, to understand all the system elements, requirements and impact.

Future research is required to assess on a larger scale the operational and technical feasibility of a DBRUC system, as scaling problems are critical to implementing such a system. Additionally, there is still a requirement to investigate and address policy, social and equity issues. This includes properly setting fee levels and understanding road user's responses to the acceptability and experience of using such a system. Scaling issues still exist to test the proposed DBRUC system in terms of operability, implementation and running cost, ethical issues pertaining to road users' perception of the system and its acceptability to them, and government policy.

Future experiments should include larger samples and involve different vehicles, including heavy goods vehicles. Refining the methodology to determine the road user charge should be the focus of future research (specifically the costs of congestion and cost of infrastructure).

The following chapter discusses the study findings and the contributions it has made to the knowledge of road cost recovery and the use of DBRUC in South Africa. It continues by reflecting on the implications the research findings hold for various stakeholders, highlights the limitations of the study, makes recommendations for future research, and finally concludes with an overarching discussion on the future of DBRUC as a road cost recovery method in South Africa.

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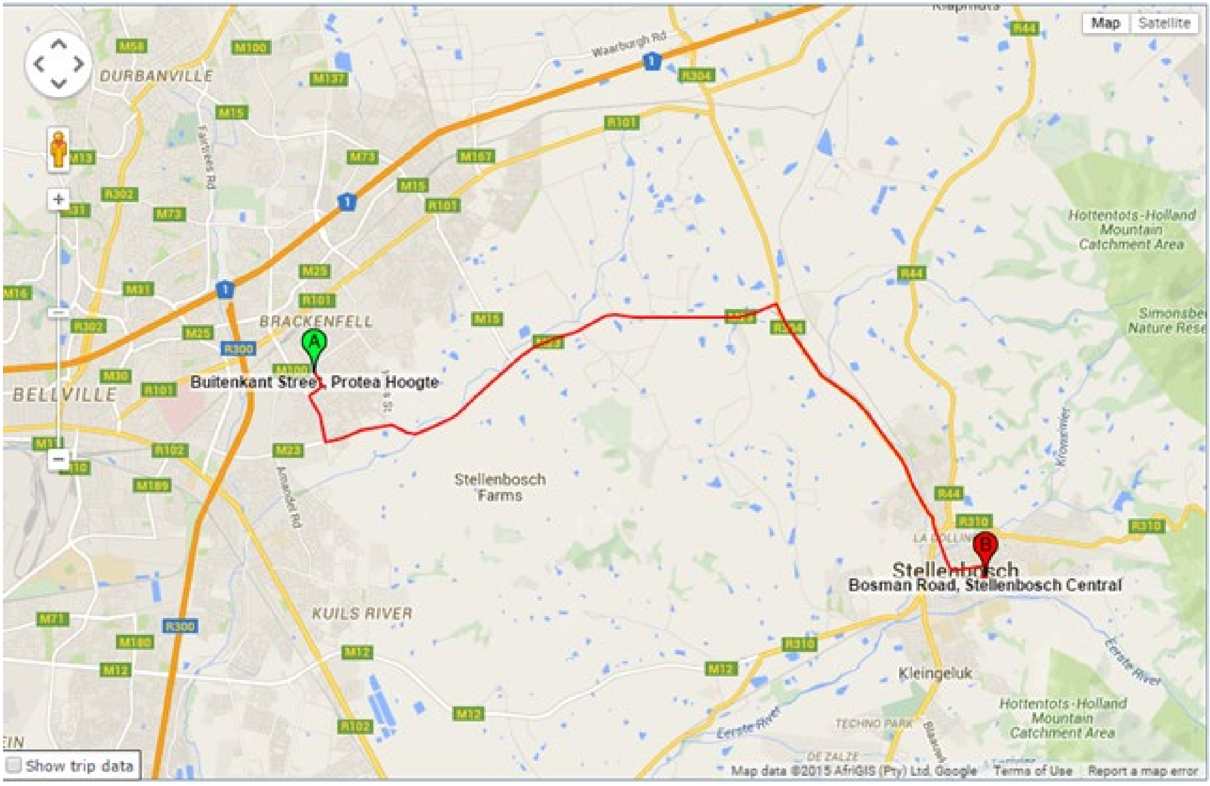
Appendix 7.A | Vehicle tracking web-based interface, 3rd party

Trip Date Time	Start Zone	End Zone	Distance	Duration	Private/ Business	Trip Comment	View
Thursday, 19 November 2015							
09:23 - 09:55	Buitenkant Street, Protea Hoogte (U)	Victoria Street, Stellenbosch Central (U)	22.77 km	32 min			View
07:59 - 08:06	Jacaranda Street, Protea Hoogte (U)	Buitenkant Street, Protea Hoogte (U)	0.99 km	7 min			View
07:51 - 07:58	Buitenkant Street, Protea Hoogte (U)	Jacaranda Street, Protea Hoogte (U)	0.73 km	7 min			View
Wednesday, 18 November 2015							
16:14 - 16:48	Bosman Road, Stellenbosch Central (U)	Buitenkant Street, Protea Hoogte (U)	21.93 km	34 min			View
09:30 - 10:03	Buitenkant Street, Protea Hoogte (U)	Bosman Road, Stellenbosch Central (U)	22.80 km	32 min			View
07:44 - 07:50	Jacaranda Street, Protea Hoogte (U)	Buitenkant Street, Protea Hoogte (U)	0.84 km	7 min			View
07:35 - 07:42	Buitenkant Street, Protea Hoogte (U)	Jacaranda Street, Protea Hoogte (U)	0.76 km	7 min			View



Appendix 7.B | Freeman model

7. B.1 | Representative vehicles for cost allocation purposes, 2017

Group	Vehicle description	Gross vehicle mass (kg)
1	Motorcars	1 200
2	LDV's - Bakkies	2 060
3	Minibuses	2 374
4	Buses	14 820
5	Trucks	32 700
6	Motorcycles	180
7	Other & Unknown	14 200

7. B.2 | Population and annual distance travelled per vehicle class, 2017

Group	Vehicle class description	Vehicle population	Vehicle population (-5%)*	Total distance travelled per annum	Average distance travelled per annum per vehicle (km)
1	Motorcars	7 071 976	6 718 377	101 407 373 905	15 094
2	LDV's - Bakkies	2 460 863	2 337 820	45 212 694 127	19 340
3	Minibuses	310 330	294 814	8 500 479 278	28 833
4	Buses	61 941	58 844	2 041 522 973	34 694
5	Trucks	371 757	353 169	16 314 584 452	46 195
6	Motorcycles	357 064	339 211	2 164 718 326	6 382
7	Other & Unknown	233 647	221 965	369 586 055	1 665
Total		10 867 578	10 324 199	176 010 959 116	

7. B.3 | Road expenditure costs to be recovered, 2017

Item	Total	percentage split of current expenditure in 2014
Operation and regulation	R69 134 692 673	58.93%
Infrastructure	R48 179 841 959	41.07%
Total	R117 314 534 632	

7. B.4 | Allocation of operational and regulatory costs, 2017

Group	Vehicle class	Operational and regulatory cost
1	Motorcars	R39 831 426 775.54
2	LDV's - Bakkies	R17 758 926 655.06
3	Minibuses	R3 338 871 769.01
4	Buses	R801 882 246.68
5	Trucks	R6 408 145 196.35
6	Motorcycles	R850 271 692.85
7	Other & Unknown	R145 168 337.69
	Total	R69 134 692 673.186

7. B.5 | Allocation of specific capital costs, 2017

Group	Vehicle class	Gross vehicle mass (kg)	Specific costs (light vehicles)	Specific costs (heavy vehicles)	Total Specific costs
1	Motorcars	1 200	R745 517 957.34	R0.00	R745 517 957.34
2	LDV's - Bakkies	2 060	R332 390 772.72	R0.00	R332 390 772.72
3	Minibuses	2 374	R62 493 088.06	R0.00	R62 493 088.06
4	Buses	14 820	R0.00	R713 362 487.10	R713 362 487.10
5	Trucks	32 700	R0.00	R5 782 214 089.79	R5 782 214 089.80
6	Motorcycles	180	R15 914 388.89	R0.00	R15 914 388.89
7	Other & Unknown	14 200	R0.00	R56 881 929.49	R56 881 929.49
	Total		R1 156 316 207.01	R6 167 019 770.71	R7 708 774 713.39

7. B.6 | Allocation of non-specific capital costs, 2017

Group	Vehicle class	PCU value	Non-specific capital costs
1	Motorcars	1.0	R14 794 274 498.89
2	LDV's - Bakkies	1.0	R6 596 058 866.31
3	Minibuses	1.0	R1 240 130 958.54
4	Buses	2.5	R744 592 086.80
5	Trucks	3.0	R7 140 381 357.50
6	Motorcycles	0.5	R157 904 873.63
7	Other & Unknown	3.0	R161 756 211.88
	Total	12.0	R30 835 098 853.54

7. B.7 | Allocation of indirect maintenance costs, 2017

Group	Vehicle class	Routine maintenance	Repair costs due to weather	Total indirect maintenance costs
1	Motorcars	R2 748 086 460.07	R305 342 940.01	R3 053 429 400.08
2	LDV's - Bakkies	R1 225 240 214.50	R136 137 801.61	R1 361 378 016.10
3	Minibuses	R230 358 514.45	R25 595 390.49	R255 953 904.94
4	Buses	R55 324 198.08	R6 147 133.12	R61 471 331.20
5	Trucks	R442 116 651.95	R49 124 072.44	R491 240 724.39
6	Motorcycles	R58 662 727.29	R6 518 080.81	R65 180 808.10
7	Other & Unknown	R10 015 587.58	R1 112 843.06	R11 128 430.64
	Total	R 4769 804 353.907	R529 978 261.545	R5 299 782 615.452

7. B.8 | Allocation of direct maintenance costs, 2017

Group	Vehicle class	Distance travelled per class	E80 kN per vehicle	Cost responsibility per class
1	Motorcars	101 407 373 905	0	R0.00
2	LDV's - Bakkies	45 212 694 127	0	R0.00
3	Minibuses	8 500 479 278	0	R0.00
4	Buses	2 041 522 973	0.80	R232 351 554.69
5	Trucks	16 314 584 452	1.75	R4 061 770 578.09
6	Motorcycles	2 164 718 326	0.00	R0.00
7	Other & Unknown	369 586 055	0.80	R42 063 643.50
	Total			R4 336 185 776

7. B.9 | Allocation of road expenditure deficit costs, 2017

Group	Vehicle class	Vehicle population	Average distance travelled per annum per vehicle	Rands							
				Operation and regulation	Infrastructure: Capital		Infrastructure: Maintenance		Total costs	Cost per vehicle per annum	Cost per kilometre
					Specific	Non-specific	Indirect	Direct			
1	Motorcars	6 718 377	15 094	R39 831 426 776	R745 517 957	R14 794 274 499	R3 053 429 400	R0.00	R58 424 648 632	R8 696	**R0.58**
2	LDV's/Bakkies	2 337 820	19 340	R17 758 926 655	R332 390 773	R6 596 058 866	R1 361 378 016	R0.00	R26 048 754 310	R11 142	**R0.58**
3	Minibuses	294 814	28 833	R3 338 871 769	R62 493 088	R1 240 130 959	R255 953 905	R0.00	R4 897 449 721	R16 612	**R0.58**
4	Buses	58 844	34 694	R801 882 247	R713 362 487	R744 592 087	R61 471 331	R232 351 555	R2 553 659 706	R43 397	**R1.25**
5	Trucks	353 169	46 195	R6 408 145 196	R5 782 214 090	R7 140 381 357	R491 240 724	R4 061 770 578	R23 883 751 946	R67 627	**R1.46**
6	Motorcycles	339 211	6 382	R850 271 693	R15 914 389	R157 904 874	R65 180 808	R0.00	R1 089 271 763	R3 211	**R0.50**
7	Other & Unknown	221 965	1 665	R145 168 338	R56 881 929	R161 756 212	R11 128 431	R42 063 644	R416 998 553	R1 879	**R1.13**
	Total	10 324 199		R69 134 692 673	R7 708 774 713	R30 835 098 854	R5 299 782 615	R4 336 185 776	R117 314 534 632		

Chapter 8. Evaluating distance-based road user charges as a road cost recovery method in South Africa

The past decade has seen growing and ongoing academic and policy debate on how to secure funding for roads and transport-related infrastructure. More recently, researchers have started to assess, design and test DBRUC programmes built on the premise of charging individual road users based on the distance that they travel. In chapter 1, DBRUC was identified as a road cost recovery method, which could be implemented within the current South African road-funding framework to possibly secure funding from road users to meet the road sector's infrastructure expenditure requirements. As objective research is required on whether this road cost recovery method should be implemented in South Africa, this study set out to evaluate the need, appropriateness and practicality of DBRUC using GPS-enabled vehicle tracking devices and a short-run MSC-based fare structure as a road cost recovery method in the South African road-funding framework. This was followed by a comprehensive literature review presented in Chapter 2 to provide a clear understanding of DBRUC and where it fits into the road-funding environment, discussing the existing knowledge and research on this system and identifying areas or challenges that require further research.

Chapter 3 subsequently aimed to evaluate the need for DBRUC by assessing to what extent the South African road-funding framework is able to secure funding for roads. This evaluation continued in Chapter 4, which assessed to what extent the current South African road cost recovery methods will be able to secure funding for roads in the future given the emergence of disruptive transport technologies and societal trends. Chapter 5 then aimed to evaluate the appropriateness of DBRUC by assessing to what extent the South African road-funding framework reflects fair and efficient road user charges. Chapter 6, continued evaluating the appropriateness of DBRUC by assessing to what extent South African road users view current and proposed road cost recovery methods within the country's road funding framework. Lastly, Chapter 7 aimed to evaluate the practicality of DBRUC by assessing to what extent DBRUC are operationally feasible and economically viable within South Africa. Chapter 8 aims to evaluate DBRUC as a road cost recovery method in South Africa given the study findings.

The chapter starts by providing an overview of the study aim, highlights the research results and discusses the contribution it has made to the knowledge of road cost recovery and the use of DBRUC in South Africa. It continues by reflecting on the implications the research findings hold in terms of the implementation of short-run MSC-based charges, the allocation of road costs, the recovery of road cost through practical road cost recovery methods and, the implications for road users and policy makers. The limitations of the research are discussed which is followed by some recommendations for future research, after which the study concludes with an overarching discussion on the future of DBRUC as a road cost recovery method in South Africa.

8.1 Introduction

Roads are undeniably important to any country as, among others; it can lead to an improved standard of living for the public, provide a social service and support economic growth and development. As their main purpose, roads allow individuals to travel to work reliably and safely, to acquire products without excessive transportation expenses or delays and to use services that depend on others to reach their destination (Terril, Emslie & Coates, 2016).

The quality and size of the road network are dependent on sufficient maintenance, timely upgrade and appropriate new construction of the infrastructure to ensure a well-maintained, effective and safe road network, which in turn is dependent on sufficient and stable modes of funding and adequate financing. Despite the general belief in the importance of roads, funding is often controversial, faces many conflicting viewpoints and is notoriously complex. This situation is amplified in a country such as South Africa, which faces numerous developmental requirements, limited revenue opportunities and a relatively small road user base.

South Africa has seen its fair share of public debate on how the government should fund transport infrastructure and, increasingly, transport operations such as public transport. A general theme in government policy papers seems to indicate their preference for adopting the user-pay principle to fund roads (Department of Transport, 2013, 2017, 2018). Currently, the main revenue source from road users in South Africa is the fuel levy. However, it is argued that there is not a strong connection between road use and the fuel levy anymore.

A brief review of international literature found that the problems associated with the fuel levy are not unique to South Africa. In numerous countries, including the USA, European countries and New Zealand, this phenomenon is also encountered. However, these nations are actively looking for feasible solutions to the decreasing fuel revenue source (Abou-Zeid, Ben-Akiva, Tierney, Buckeye & Buxbaum, 2008; Sorensen & Taylor, 2005; Whitty & Imholt, 2007). The most innovative cost recovery method currently being researched is DBRUC that charge vehicles directly for each km driven. This system is considered the best solution to the present issues presented by the fuel levy (Coyle, Robinson, Zhao, Munnich & Lari, 2011).

Although securing funding for the road sector in South Africa is more challenging than ever while competing with other economic responsibilities, the current scientific debate on road cost recovery includes several areas that require further research before a DBRUC system can be implemented in South Africa. First, local allegations that the conventional fuel levy is not sufficient any more to fund road construction, maintenance and upgrades have led to a fiery debate about the future of using this model as an economically efficient road cost recovery method. This was made apparent with mass protest action, court cases and payment refusal with implementation of the controversial Gauteng Freeway Improvement Project (GFIP), as from 2015, which intended to recoup more road user cost from motorists to provide upgraded road infrastructure and alleviate congestion. What is unknown within the South African context is the extent to which the country's road-funding framework and its road cost recovery methods are able to secure funding for roads as the proses is not administered by a central authority, but rather adjudicated to various governmental spheres as mandated in the South African Constitution. Second, road cost recovery methods revenue will be impacted by future technological improvements. Third, local policy documentation does not seem to have a clear mandate about how to recover cost nor how to set fair and efficient prices, simply referring to the user-pay principle that should be adopted. A road user charge policy seems lacking locally, although it has become standard internationally. Fourth, it is furthermore unknown how road users and non-road users perceive road pricing or will perceive a new road cost recovery method such as DBRUC and whether it will be publicly accepted in the current political environment. Fifth, a DBRUC programme has not previously been tested in South Africa and it is unsure whether it is operationally feasible and economically viable, especially in South Africa's current economic climate with its current technological infrastructure.

The following aim was therefore formulated for this study:

> To evaluate the need, appropriateness and practicality of DBRUC using GPS-enabled vehicle tracking devices and a short-run MSC fare structure as a road cost recovery method in the South African road-funding framework.

Therefore, this chapter aims to evaluate DBRUC as a road cost recovery method in South Africa given the study findings. This will be done by i) collectively discussing the research findings of the study and the contributions made to the field of study, ii) providing policy recommendations, iii) highlighting the limitations of the study, and iv) making recommendations for future research.

8.2 Overview of results and knowledge contribution

To address the aim of this study, five research questions were formulated in Chapter 1 of this study. The current section summarises and interprets the findings from Chapter 3 through 7 that have addressed these questions.

In Chapter 3, research question 1 was addressed which asked to what extent is the South African road funding framework able to secure funding for roads? In order to answer this research question the study i) quantified the South African road funding framework through a budget analysis, ii) compared the quantified South African road funding framework internationally through a comparative analysis, and iii) measured the economic efficiency of the South African fuel levy through a productivity analysis.

Through a budget analysis for the period, 2010 to 2014, the magnitude and levels of funding from all government departments across all three spheres of government and road-related SOEs and the distribution, allocation and expenditure of these funds were assessed. All of this information was then consolidated into one comprehensive record for analysis. The analysis illustrated that there are a various funding sources of different magnitude in South Africa's road funding framework and that not only the fuel levy is important but other taxes as well.

At present, the South African road-funding framework is able to secure a sizeable amount of funding from road users through its road cost recovery methods that are based on actual use of the road network and vehicle ownership. The fuel levy, however, through national government, still contribute the biggest proportion of this funding. Through annual adjustments, the road cost recovery methods' revenue potential is growing significantly, i.e. more than the vehicle fleet, and is adjusted to a level above inflation. Speaking on the distribution of these funds collected there seems to be numerous beneficiaries - each with different mandates. These mandates are not solely based on road construction and include administration and regulatory functions. Only about a third of all funding collected is allocated for the purpose of road construction, but ultimately around 50% is spent on road expenditure whereas the other half is spent on administration and regulatory purposes. It is apparent that the revenue sources through the various road cost recovery methods are not aligned with road expenditure, leaving a shortfall in funding that must be covered by other sectors of the economy.

Through a comparative analysis, the revenue and expenditure of the South African framework was assessed by considering numerous other countries' frameworks in terms of their road expenditure to revenue ratio, their road expenditure to GDP ratio and their road allocation to revenue ratio. South Africa seems to be relatively on par with how much funding is generated, allocated and invested in the road network compared to other countries. However, in terms of the road expenditure to GDP South Africa tend to be on the high end but not below the norm, but this is to be expected of a country still developing and which has an extensive road network coupled with the focus of infrastructure-led growth and job creation.

A productivity analysis has been conducted to evaluate South Africa's fuel levy in terms of other countries' fuel levies. The fuel levy and price of fuel appear to be relatively cheap compared with other countries. In addition, the revenue from fuel levies also has an impact on alternative fuel, electric vehicles and vehicles that are more efficient. While the registered population of South Africans grew 47.2% between 2003 and 2012, vehicle km increased by 38.5% and fuel sales increased by only 21.9%. However, the fuel levy loses its productivity compared to different indexes. This results in less revenue each year per unit of consumption or km per vehicle being generated by the fuel levy. The fuel levy should therefore have been increased more than it has been in recent years to keep up with current trends in road construction. However, that would have had many negative repercussions on road users and on the economy, such as lower revenues to spend on others and higher prices for goods and services.

In Chapter 4, research question 2 was addressed which asked to what extent will the South African road cost recovery methods be able to secure funding for roads in the future given the emergence of disruptive transport technologies and societal trends? In order to answer this research question the study i) forecasted the revenue of South Africa's road cost recovery methods through a trend line forecast, and ii) estimated the potential revenue impact of disruptive transport technologies and societal trends on South Africa's road cost recovery methods through scenario analysis.

Focussing on the South African road-funding framework, the study identified several technological and societal trends that may have an impact on future road-generated revenues. Forecasting these revenues, through a time series (ARIMA) forecast and using scenario analysis, showed that although new technology will have an impact on future road-generated revenues, it is more incremental in the short to medium terms than disruptive as previously envisaged. However, the shortfall of 19% in 2050 will become the responsibility of road users who will have to pay the shortfall through higher fees and charges or, alternatively, the aid will come from other sectors of the economy. Luckily, the impact of disruptive and social trends will not be so bad for South Africa if it is compared to countries that have a dedicated road fund. Thus, the revenue that is lost will be captured through other taxes or charges due to road users having more disposable income to spend on other expenses. The results further show that full-scale adoption of especially EVs and reduced vehicle ownership due to e-hailing services will have a profound effect on road-generated revenues, especially revenues collected through fuel-based cost recovery methods. Future road-generated revenue projections will become inaccurate and will have a detrimental effect on budget planning if sufficient attention is not paid to the possible impact that disruptive transport technologies may have. Government departments and road-related SOEs tasked with collecting fees and charges from road users have to be aware that disruptive technologies are present and that more will emerge in the near future.

In Chapter 5, research question 3 was addressed which asked to what extent do the South African road funding framework reflect fair and efficient road user charges? In order to answer this research question the study i) calculated the impact of the South African road funding framework for road users through an impact assessment, and ii) derived a short-run MSC-based road user charge through the use of the social economic cost responsibility principle and purchasing power parity (PPP) theory.

These results clearly indicate the very different outcomes that can be obtained using the different charge calculation approaches and the sensitivity of the final road user charge to the available cost data. However, the findings do seem to indicate, simply based on comparison with international data and road user charges, that South Africans are already paying a fair price for road use in rural areas but that urban and peak hour road user charges may not cover road user costs.

In Chapter 6, research question 4 was addressed which asked to what extent South African road users view current and proposed road cost recovery methods within the country's road funding framework? In order to answer this research question the study i) collected public opinion regarding the fuel levy and DBRUC through an online survey.

When the respondents were asked if they are aware that included in the price of fuel, they are paying for their use of the road network through a fuel levy, 90.5% of them indicated that they are aware but only 41.5% knew that the fuel levy is generating less revenue per vehicle km due to an increase in vehicle fuel efficiency and the increasing use of electric vehicles. With a brief explanation of what DBRUC entails, the respondents further indicated that they are relatively unaware (69%) that a DBRUC may be a fair payment system for road use that would also generate sufficient revenue for improvements to roads and related transport systems.

Of the 543 respondents who said they knew they were paying for their use of the road network through a fee included in the fuel price, only 20.5% (111 respondents) knew what portion of the purchase price of a litre of fuel is earmarked as fuel levy currently. Of these 111 respondents, only 23.4% knew the exact amount of fuel levy current levied at R3.37 per litre of petrol. Of these respondents, 27.9% under estimated the fuel levy amount while 48.7% of respondents overestimated the fuel levy amount.

Of the 543 respondents who said they knew they were paying for their use of the road network through a fee included in the fuel price, 92.6% indicated that they do not know how much fuel levy they pay per km of road use.

More than half of the respondents (57.8%) said that they do not know what the fuel levy can be used for. Although not mutually exclusive, when asked to indicate for which programmes the fuel levy should be used, the respondents (n=619) showed overwhelming support for roads

(87.2%) and moderate support for public transport (52.2%). They did not favour general government expenditure (4%). Only 6.5% of the respondents indicated that all three programmes should be funded by the fuel levy, as is currently the case in South Africa.

A TURF analysis showed that if government only used the fuel levy to fund roads, it would be accepted by 87.2% of all respondents. If government were to use the funds generated to additionally fund public transport, it would satisfy 90.5% of all respondents.

Of the respondents, 76.3% did not know what a DBRUC system entails or how it would work. Although most questions on public opinion of DBRUC in the USA are based on the notion that a distance fee system should replace the current fuel levy, some institutions did ask some stated-preference questions. The Minnesota Department of Transportation found in 2011 that 79% of respondents (from a sample of 400) were unfamiliar with the notion of paying by traveling distance. That was in the period when the American public were relatively unaware of any research or pilot programmes involving the new charging system. A similar observation was made two years later by Indiana University, which found that 81% of 2087 respondents have never heard or seen information about distance user fees. It was only in 2013 that the State of Oregon began actively researching distance fees through vehicle tracking studies and it was more widely reported on across the USA.

When asked if the respondents knew the exact amount that they had to pay per km to recover the cost of them using the road network, hinting that the cost includes externalities such as congestion, environmental and accident cost, only 2.8% indicated that they knew this amount. This amount varies between amounts less than R0.01 and R10.00.

Of the respondents in South Africa, 87.7% indicated that they do not know for what the road user charge that they will pay through a DBRUC can be used. When asked to indicate for which infrastructure programmes the DBRUC system should be used, the respondents (n=619) were largely unsure with roads only receiving 10.8% support and public transport 7.2%.

The analysis indicates that the public is mostly concerned with the fact that they cannot easily calculate the fee that they pay or must pay for each trip that they undertake. Furthermore, they do not think it is an efficient system to make road users aware of the total cost involved in using the road and as such do not use any appropriate technology to accurately calculate this cost.

The public is furthermore also dissatisfied with the trustworthiness of the system and the fee levied is not transparent in how it is calculated or for what it is used. It is noted that the spread in dissatisfaction is much more than the spread in importance. This suggests that respondents are unsatisfied, but they do not have an answer. This may be an indication of ignorance or a symptom of corruption (Figure 6.1).

Analysis of the public's perception towards the DBRUC shows rating scores centered on the data centroid and scale median, indicating no perceived public opinion. This is not unexpected, as this system should be fairly new or unknown to them. What is apparent is that privacy is seen as the attribute that concerns most of the public, which is the opposite in the case of the fuel levy. Furthermore, the public is concerned with the trustworthiness of the system and about whether it will be accepted by all road users (Figure 6.2). These issues should be addressed and communicated as a priority to ensure a smooth transition to the new system with higher public acceptance.

The public indicated that less than half of them (46%) change their travel habits and patterns when the fuel levy is increased. The respondents would mainly travel less (34.3%) and avoid peak hour travel (18.3%).

In turn, 53% of respondents indicated that they think that having access to their road use cost by means of an invoice may motivate them to change their travel behaviour. The respondents would travel less (36.7%), avoid peak hour traffic (25%), and use alternative routes (26%), use public transport (22%) and carpool (18.8%).

When asked to use a scale of 1 to 10, where 10 implies very acceptable and 1 means completely unacceptable, 47.5% of the respondents rate the current system of a levy on every litre of fuel purchased at the pump as a method of raising funds for South Africa's road sector as relatively unacceptable (rating score of 1 to 4), whereas 35.5% rate the fuel levy as relatively acceptable (rating score of 7 to 10) with a mean score of 4.8.

When asked to use a scale of 1 to 10, where 10 implies very acceptable and 1 implies completely unacceptable, 36.9% of participants rated the system of a DBRUC system as a technique of raising funds for South Africa's road industry as comparatively unacceptable (rated as 1 to 4), while 29.2% rated the DBRUC system as comparatively acceptable (rating score of 7 to 10) with a mean score of 4.8.

The respondents indicated that their preferred method that the government should use to generate revenue for the funding of South Africa's roads is the conventional fuel levy followed by DBRUC. In addition, they favoured vehicle license fees followed by general taxes. However, they indicated an overwhelming disfavour in the usage of toll roads.

If government only uses the current fuel levy system as a method to generate funding for roads it would satisfy only 30.7% of respondents. Adding a DBRUC system would increase the reach to 55% of respondents. This reach could be increased to 77.4% if government taxes were also used. Thus, 77.4% of all road users would be satisfied with the method used to fund South Africa's roads if only government implemented these three systems.

It seems that respondents 35 years and younger are more open to the notion or favourability towards DBRUC whereas respondents of 36 years or older are more in favour of the fuel levy.

In Chapter 7, research question 5 was addressed which asked to what extent are DBRUC operationally feasible and economically viable in South Africa? In order to answer this research question the study i) generated a DBRUC invoice in South Africa through a vehicle tracking study, and ii) calculated the revenue potential of a DBRUC system in South Africa through a cost allocation analysis.

A DBRUC system was found to have many configurations comprising various key technical components that should be taken into consideration. These components include the purpose of the implementation, which vehicles and users to be charged, technological devices for measuring km travelled, communication of the vehicle travel data, the type of road to be charged, the time of day that will be charged, how much should be charged, invoice billing, enforcement of the system, protection of privacy and value-added services.

A vehicle tracking experiment has shown that a suggested configuration of the system is operationally feasible on a small scale in South Africa. A removable on-board GPS unit with GSM technology was acquired from a third-party tracking company. Installation was quick and the service was easy to use. Data pertaining to the vehicle's movement was secure and only available to the participant and researcher via a web-based interface. Vehicle travel data was readily available in the correct format for analysis and a road user invoice can be constructed with ease, charging the vehicle owner for the distance travelled at a set rate per km.

Furthermore, a comparison was made between four road pricing methodologies that included the current fuel levy used in South Africa, the fee structure used in OReGO, USA, a simplified average costs model devised for South Africa in 1980 and an approximate margins social cost approach. The results show that the conventional fuel levy delivered the smallest revenue while the MSC approach delivered the biggest revenue. This can be attributed to the congestion cost element associated with the MSC due to the peak time and urban focus of the majority of trips. The results further show that a cost allocation approach is key in ensuring the effective cost recovery of all road costs incurred. A fee structure based on the fuel levy is not effective and is subject to the fuel efficiency of the vehicle being operated. The best option is to use a MSC fare structure that incorporates infrastructure, accident, and environment and congestion costs.

8.3 Research implications

Overall, this study supports the suggestions made in several studies that have called for DBRUC to be incorporated into road-funding frameworks through the use of GPS-enabled vehicle tracking devices in order to secure funding in an equitable way to fund road maintenance, upgrades and new construction. However, the insights from the methodological contributions and empirical analysis presented in this study have several implications for current methodological discussions on the implementation of short-run MSC fare structures in road cost recovery, for theoretical discussions on the allocation and the recovery of road costs through practical road cost recovery methods in general, and for road users and policy makers.

8.3.1 Implementation of short-run MSC-based road user charges

The study have shown that the calculation of MSC is by no means an easy endeavour. This calculation is data intensive, which at current South Africa cannot collect without employing technology on the user level. This can be addressed by following the OReGO model where participation in a DBRUC system is voluntary. The user base can be increased over a number of years while the current South African road cost recovery methods are still able to collect sufficient revenue from road users while not expanding on the already unequal payment of cost by motorists based on the vehicle type that they can afford. In this manner the DBRUC system can be tested and improved on small scale, ironing out issues that might not have such a big effect on a small user sample than a larger one. This will allow for systematic collection of location and cost data that can be fine-tuned to be able to calculate a workable short-run MSC structure. As such the success of DBRUC in South Arica relies on accurate data on the maintenance, congestion, accident and environmental costs of road transportation.

8.3.2 Allocation of road cost

As stated in Chapter 3, only a handful of users are charged with the funding of the road network that benefits all South Africans. Transport is a derived demand, without it other sectors would not exist. It is exactly this need for goods and services that requires an efficient transportation system. Thus roads are essentially used by all residents in a country, and not just actual motorists. An argument can be made that in this instance all residents is responsible to maintain the road network. A widely accepted and effective cost recovery mechanism is the value-added tax system, which might be useful to secure at least the maintenance cost needed for road infrastructure. It must be noted that if a road is used or not, it still requires periodic maintenance to be performed. In this manner the road cost that needs to be recovered can be done so in the most social economic way by allocating the road cost to all people that buy goods and services. Consequently, the fuel levies (and other vehicle and usage taxes and fees) will be removed from the price of fuel that would make transportation cheaper. This leaves motorists with more disposable income, which if not saved will be captured by another revenue collection method. As most of South Africa's road cost recovery method's revenue that is collected accrue to the national expenditure fund, the same fund as where value-added tax goes, this might be a favourable avenue especially in detangling the complicated flow of funds in South Africa's road funding framework. The effect that this might have on the demand of goods and services, and the overall economic effect needs to be investigated. Distance-based road user charges can then be implemented to only charge for actual road usage based on short-run MSC. In this manner road users will become aware of the actual road cost they incur and can result in a change in travel behaviour through adjusting the price mechanism.

8.3.3 Recovery of road cost through practical road cost recovery methods

Relying on the fuel levy as the primary funding source for roadway infrastructure is becoming less effective as the traditional means of transportation starts to take its toll. A continuous increase in the fuel levies results in an increased demand for hybrid or fuel-efficient vehicles, this leads to a financial gap in road maintenance and transport infrastructure provision. Due to the increasing variety of vehicle and fuel types, the fuel levy will only become more unreliable in the future. An alternative source of funding, such as the DBRUC, which will potentially replace the fuel levy in the near future, has to be taken into consideration by the government as well as the public. However, convincing the public that this type of change is required is easier said than done.

One of the reasons why an additional road funding model, like the e-tolls, did not live up to its potential is due to a lack of public support as well as failing to understand public perception. Sending out the wrong message to the public can have major implications regarding public acceptance. Many initiatives tend to disregard the importance of public opinion. Understanding public opinion and level of acceptance can positively contribute towards how policies should be set during the implementation process.

8.3.4 Road users

Although it may seem that road users are paying less road user cost per km of travel, this does not mean that the government is missing this revenue. As the fuel levies and other road cost recovery revenue accrue to the National Treasury, this entity also has numerous other methods to collect revenue from road users and the population. If there is a saving for road users in terms of their road user cost, this means that they will have more disposable income for other goods and services. Here a form of tax that would now collect more revenue from the road users might be levied. Thus, the money is not lost due to technological advancements, as funding for the road sector is not earmarked (ring-fenced). Even though road users pay less, the road sector will still receive a comparable source of funding from government. A problem will only manifest itself if the funds collected from road users accrue to an earmarked or ring-fenced fund.

The adverse effect of cheaper transport cost or reduced road cost recovery funding paid by the road user may result in more travel by the road users. Thus, the road funding that is lost per unit of travel will be made up by more travel from the road users.

Reduced fuel usage result in less government revenue, but may have other macro-economic benefits. This includes a reduction in the imports of Brent-crude oil, petrol and diesel that may be replaced with locally produced electricity, which might have a positive impact on South Africa's international valuta reserves, the Rand exchange rate and economic development.

8.3.5 Policy makers

The study showed that South Africa has built itself into a situation where it is not able to recover enough funds for road construction, maintenance and upgrades. This is mainly due to the small user base operator on the countries extensive road network. Where roads are located and used most often is not in the same place.

In addition, too much beneficiaries require funds from the national government to sustain the road network. National government cannot fulfil this requirement and it must become the responsibility of provinces and metropolitan areas to generate more funds for roads.

Road users are already paying their fair share of road user cost and adopting the user pay principle as proposed in South Africa will not guarantee additional revenues except when conditions are right. This will come mainly from congestion taxes in the metropolitan areas.

The study has shown that road users do not have the correct knowledge about the South African road-funding framework, which entails, how it collects money and what is done with this money. Under these circumstances, it will be difficult to advocate for any new road cost recovery method.

8.4 Research limitations

This study has provided important innovative insights into the evaluation of the requirement, appropriateness and practicality of DBRUC using GPS-enabled vehicle tracking devices and a short-run MSC fare structure as a road cost recovery method in the South African road-funding framework. Nevertheless, there are some methodological and theoretical shortcomings of this study.

Data is difficult to find and the researcher has tried everything to eliminate errors, but due to the complexity of the data and road funding, errors cannot be completely excluded. It is therefore a recommendation of the study that South Africans should begin to improve South Africa's means of data collection. It also means South Africa cannot make unqualified comments.

A first limitation is found in the calculation of the MSC structure as set out in Chapter 5. The discussion should not be seen as an accurate representation of MSC-based road user charges in

South Africa. It is merely an attempt to illustrate how MSC can be derived in South Africa, the data requirements that will be required to establish the approach and the possible impact of the approach on existing road user charges. Implementing road user charges based on the MSC-pricing approach is dependent on; an understanding of the system by all the relevant parties; an appropriate policy framework; data supporting the calculation of the various external cost; accurate costs accounting procedures and accurate vehicle fleet and road user information.

A second limitation is found in the sampling of the respondent base during the public opinion survey on road user charges. The representativeness of the sample to the population of South Africa is questioned as most respondents live within the Western Cape Province of the country, which only represents 7% of South Africa's population. These respondents were mainly from urban areas and thus the perspectives of road users from rural areas were not effectively collected. The method employed to collect the opinion data also lends itself to scrutiny as responses was limited to road users who reads newspapers, use social media and where employees or contacts of the large employers to whom the survey was sent.

A third limitation can be found in the vehicle tracking study. Although the purpose of this experiment was purely to assess the operation of a DBRUC system in South Africa, the sample size is not representative.

8.5 Recommendations for future research

Through the usage of GPS-enabled vehicle tracking devices and a short-run MSC fare structure, this study has provided important insights into the recovery of road cost using DBRUC in the South African road-funding framework. Nevertheless, some important issues have remained unexplored. This final section presents recommendations for future research that could help address some of the limitations.

South Africa needs a road authority that take sole responsibility for the allocation and collection of road cost and then the distribution of this income to the appropriate stakeholders. For this to happen a comprehensive road funding policy is needed, that not only indicate the need for funding and advocate for the implementation of the user-pay principle, but to accurately reflect in a central document the flow of funds from and to the road network and through which mechanisms it comes.

Building on deriving fair and efficient road user charges, there is a requirement to accurately calculate all cost road users impose on the road network and society. Accurate costs of road externalities are required and at current this makes the calculation of MSC fares very difficult and can only be estimated.

It would also be advantages to assess road users' opinions of the fuel levy and DBRUC before a system implementation, allowing time for the users to test the system and then assessing their opinions again after implementation of the system. This will allow for a longitudinal study to assess the effect of the system on travel behaviour.

On the road use data collection side, the use of different metering methods should be further explored, as the vehicle tracking studies undertaken during this study only focussed on using GPS-enables vehicle tracking devices. These different metering options available will have an effect on the cost of the system and public acceptability. Metering methods can be distinguished between low-tech and high-tech options, each posing their own advantages and disadvantages which may include time permits or self-reported odometer checks.

In terms of testing a DBRUC system, the sample size of participants needs to be greatly increased. Given the current cost of infrastructure to implement such a system, great amount of funding is required. This funding could possibly come from the public sector if they can be persuaded of the benefits that such a system can hold.

8.6 Discussion and conclusion

The main aim of this study was to evaluate the requirement, appropriateness and practicality of DBRUC using GPS-enabled vehicle tracking devices and a short-run MSC fare structure as a road cost recovery method in the South African road-funding framework. Innovative road cost recovery methods, such as DBRUC, provide unprecedented opportunities to collect accurate data on road users' vehicle movement where efficient and fair road user charges can be assigned to collect road cost in an equitable manner and possibly secure funding for road maintenance, upgrades and new construction.

It is advised that DBRUC be considered to form part of the current road funding framework in South Africa as a supplementary road cost recovery method. Although there are many issues that should still be addressed, it is an avenue worth considering.

The application of DBRUC is not defined only to what is discussed in this paper, which initiated several other avenues of transportation research. Firstly, the speed of motor vehicles is at the core of the estimated 1.2 million people that are killed and the 50 million that are injured in road crashes worldwide each year. The World Health Organisation expects these figures to increase by 65% over the next 20 years in the absence of a real commitment to speeding prevention. South African policy documents indicate that traffic offences is monitored, but there is not a national monitoring programme for speeding. It furthermore states that law enforcement actions should be aimed at addressing road user behaviour and be an adequate deterrent to encourage road users to obey the law. A study was undertaken that examined the extent to which data sourced from GPS-enabled vehicle tracking devices can monitor and convey information to motorists in order to reduce vehicle speeding. By means of a proof-of-concept experiment, a motorist's vehicle was tracked for a period of seven weeks in 2019. The vehicle tracking data logged the location and time of speeding events, and then matched this with the appropriate speeding fine to be charged. The first two weeks was used as a control period where the location, time and severity of speeding events were assessed. The subsequent two weeks was used as an infographic period where information pertaining to speeding events was conveyed to the motorist everyday through a visual map and possible fines that could have been incurred. The last three weeks was used as a control period again to see if any change in travel behaviour, as a direct result of the infographic period, was still present. The analysis found that by informing the motorist of when and where speeding took place, combined with a shock factor of speeding fine values on a daily basis, a voluntary change in travel behaviour could be achieved to reduce vehicle speeding. Data showed an 80% reduction in speeding events and an 88% reduction in illegal speeding events between the control and infographic period.

Secondly, postponing road maintenance results in high direct and indirect costs. If road defects are repaired promptly, the cost is usually modest. If defects are neglected, an entire road section may fail completely, requiring full reconstruction at three times or more the cost, on average, of maintenance costs. The South African National Road Agency Ltd. (SANRAL) estimates that repair costs rise to six times maintenance costs after three years of neglect and to 18 times after five years of neglect. To avoid such escalating costs, SANRAL first allocate its available funding resources to ideal maintenance actions (e.g., reseals and overlays), and thereafter to more extensive maintenance actions (e.g., rehabilitation), and finally to new construction. However, given the social economic needs faced by provincial and municipal legislatures, adequate funding for and routine maintenance on individual roads are often neglected although road users essentially pay for these roads through road cost recovery methods such as the fuel levy. This lead to a study examining the extent to which GPS-enabled vehicle tracking devices can allocate and recover road cost, focussing on the fuel levy, to secure funding for individual road maintenance programmes. During 2019, five vehicles were tracked through GPS-enabled vehicle tracking devices in the City of Cape Town Metropole. The tracking devices provided information on the distance each vehicle travelled on individual roads. Furthermore, the fuel efficiency of each vehicle that were tracked was assessed in order to estimate the fuel levy used for each km of travel. The fuel levy used per km for each vehicle was then multiplied by the distance the vehicle travelled on each individual road to determine the amount of fuel levy that can be allocated to each road. Subsequently the routine maintenance cost which include, but not limited to, crack sealing, cleaning drainage structures, cutting of grass and reseal cost was estimated for each individual road. Using annual average daily traffic for each individual road the cost that each vehicle should pay for routine maintenance was calculated and compared to that which the vehicle already pays in terms of the fuel levy. The analysis found that it is possible to allocate the fuel levy to individual roads for vehicles using GPS-technology and that the actual cost each vehicle must pay for routine road maintenance on each individual road can be calculated to be recovered from road users. The study argues that a Road Fund Administration in South Africa can use this concept to create and manage individual road maintenance accounts and allocate the revenue to the government jurisdiction entrusted with maintaining the individual road as required, and thereafter allocate the remaining revenue to the national fiscus to be used on other social economic needs.

It is envisaged to continue researching this topic by greatly expanding on the sample size of the vehicle tracking study by forming a partnership with national government. Interest into research on DBRUC was also shown by researchers involved in the OReGO programme in the USA, which could set the scene for international collaboration on this topic. At a student level, research into DBRUC has also started to be undertaken with specific interest into pay-as-you-drive vehicle insurance.

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