DRIVE: A DISTANCE-BASED ROAD USER CHARGE VOLUNTARY EXPERIMENT

J VAN RENSBURG and S KRYGSMAN

Department of Logistics, Faculty of Economic and Management Sciences, Stellenbosch University, Private BagX1, Matieland, 7602 Stellenbosch, South Africa, Tel: 021-808 2879; Email: javrens@sun.ac.za

ABSTRACT

International research has shown that continuing reliance on the fuel levy as the main income source for road maintenance and upgrading is not viable. Technology trends such as electric vehicles and increased fuel efficiency has made the levy “unproductive”. New technology such as Global Positioning Systems (GPS) and mobile communication is making distance-based road user charging feasible. This paper provides a proposed design for voluntary participation of a distance-based road user charge experiment for South Africa based on the experiences of international program roll-outs. Selected American and European state’s distance-based road user charge designs and experiments are reviewed and a tailor-made program, designed for implementation in South Africa within the next couple of years, is proposed. A pilot project, tracking 18 voluntary participants, provided valuable information about the system’s technical requirements in the South African environment and how the road user charge could be calculated for economical and efficient road user cost recovery. The project involved a website where voluntary participants could learn more about this concept. They could apply to be part of the experiment, and once registered and a GPS device installed in their vehicle, they could view their daily travel behaviour through a mobility dashboard and map. An invoice accompanied the mobility information for hypothetical payment of road infrastructure use, based on the type of vehicle and road used, time of travel and travel conditions.

1. INTRODUCTION

Funding for roads has and continues to be faced with a multitude of challenges. In South Africa the fuel levy, which has for decades been the mainstay of road funding, has experienced declining effectiveness and efficiency in recent years due to technological, social and policy trends and advances (Van Rensburg & Krygsman, 2015). During 2014 the tax contributed 47% to the revenue collected from road users (2% less than in 2010) and constitute 5% of the total tax collected in South Africa (Department of Logistics, 2017). International trends such as technological advances whereby vehicles’ fuel economy continuously increases on average by 1% per annum, the introduction of electric and hybrid vehicles, alternative fuel sources and social trends such as car sharing may further impact on our continuing reliance on the fuel levy. (Van Rensburg & Krygsman, 2016).

Although these technological advances negatively impact on the extent to which traditional road user cost recovery mechanisms can generate sufficient revenue, it has opened up an avenue for new systems to be implemented. These systems may even overcome some of the problems with conventional road user cost recovery mechanisms. One such system is electronic road charges that charges all road users based on actual road use and that is differentiated by distance, time of day and type of vehicle. This system is deemed to be a good solution to the problems associated with the fuel levy as it is not influenced by technological and social trends, is not dependent on fuel sales, it can be a progressive tax and can accurately relate road use to road cost (better implementation of the user pay principle). It is potentially a policy-sensitive alternative whereby a change in the tax can induce a change in road user behaviour. Although theoretically sound as discussed by various researchers, full scale implementation of the concept 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 obligatory. A number of pilot projects are being undertaken to solve some of these issues, and experiments and programs underway in the USA, the EU and Asia are illustrating the practicability of the concept. In some parts of the world the system is already functioning for heavy goods vehicles to a certain extent. This paper proposes a voluntary distance-based road user charge (DBRUC) system design for South Africa and tests the system through a vehicle tracking experiment.

Section 2 of the paper provides an overview of international DBRUC initiatives. Section 3 describes the proposed South African DBRUC program and very crudely calculates an appropriate fee structure per kilometre. This is followed by a description of the methodology developed for the voluntary experiment. The next section describes and discusses the findings of the experiment with Section 6 touching on the envisaged cost structure. The paper concludes with a recommendation to further explore the concept of DBRUC and a discussion on future research and development work.

2. INTERNATIONAL EXPERIENCE WITH DISTANCE BASED ROAD USER CHARGING

Several countries have implemented DBRUC schemes or are experimenting with pilot programmes. In the USA, several pilot programmes are underway motivated, in part at least, with the pressure in the National and State Highway Trust Funds to collect sufficient revenue. The California State Transportation Agency, through the California Department of Transportation, launched the California Road Charge Pilot Program on a state-wide level based on a time and mileage-based road user charging system. The initial exercise ran from 1 July 2016 until March 2017 (State of California, 2017) and the field trail involved more than 5000 volunteer participating vehicles. Various road charging methodologies were tested whereby volunteers were given the option to choose a mileage reporting option that suites them the best. 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) a odometer charge where payment is remitted after periodic manual odometer readings and (iv) automated mileage reporting.

The Oregon Department of Transportation launched OReGO on 1 July 2015 based on the same concept (State of Oregon, 2017). Oregon was the first state in the USA to implement a fuel tax 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 user 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 rideshare) more frequently. The pilot program is a field trail with more than 5000 volunteer participating 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 30 cents US per gallon of fuel sold. It works on an average fuel efficiency of 20 miles per gallon resulting in a 1.5 cents US charge per mile. Road use invoices are issued to volunteers on a monthly bases, which indicate the fee to be paid for road usage after a rebate of the vehicles fuel tax already paid at the pump. These two neighbouring states are currently also investigating an intrastate road user charge system.

In Austria, a state-owned toll operator launched ASFINAG in 1997 on all motorways to charge road users tolls and usage charges (ASFiNAG, 2017). ASFINAG is the collection of tolls via electronic means which includes (i) car toll (toll sticker which is a time-based toll for vehicles with a maximum gross weight of up to 3.5 t), (ii) heavy goods vehicle toll (GO-Box which is a mileage based toll using microwave technology) and (iii) special tolls also referred to as a section toll. A concessionaire in Belgium, the Brussels-, Flemish Region and Walloon concessionaire Sofico launched Viapass on highways and urban roads based on kilometre charges from 1 April 2016 (Viapass, 2017). All trucks with a gross vehicle weight of over 3.5 t must be equipped with an On Board Unit (OBU) when driving on public roads.

In the Czech Republic the Ministry of Transport and the Roads and Motorways Authority launched MYTOCZ on highways and motorways from 2007 based on tolls and vignettes (MYTOCZ, 2017). To be able to pay toll, each vehicle over 3.5 t must be equipped with an on-board tolling unit, which is not transferable to other vehicles. The Hungarian Government has designated the National Toll Payment Services PLC (NÚSZ Zrt.) to launch HU-GO on its public road network from 1 July 2013 based on an electronic distance toll system (HU-GO, 2017). In turn, the New Mexico Taxation and Revenue Department in the USA, launched the New Mexico weight distance tax on a state-wide level based on a weight and mileage system (New Mexico Taxation and Revenue Department, 2017).

Through assessment of these initiatives it is apparent that international countries are moving towards weight / distances-based charges for road users as more experiments and pilot programs are being successfully implemented. Their experience indicate that the success of a local road user charge system depend on 5 main design characteristics. These are first the *technology*, which is currently available to run such a system and which can only improve in the future; second *inclusivity*, whereby all road users are part of the system and not only heavy goods vehicles as the case in the EU; and third *acceptability*, that will limit the level of resistance from road uses and create an environment for voluntary participation of such a system. Furthermore the system must be *trustworthy*, which entails the entire cost

recovery approach, the organisation collecting the data, and the fee itself. Lastly *accuracy*, whereby the charge levied is equitable across all road users.

3. PROPOSED SOUTH AFRICAN SYSTEM DESIGN

Given international experience, and in fact the current political climate in South Africa regarding payment for road use, it is important that South African road user charge systems in general, through its experiments, also adopt a volunteer approach. The experiment should follow a phased implementation plan that progressively work toward an improved and bigger system through trial and error. This will ensure greater acceptance through which all road users can experience the system and assess the added value to their daily travel (without any obligation). The participants must be given the opportunity to withdraw at any time, without penalty as this is a simulation, to create an inclusive environment set on testing the system and gaining information on user perspective, experience and acceptance.

A local system currently being tested in South Africa is referred to by the acronym, DRiVE (Distance-based Road user charge Voluntary Experiment), and is a small scale experiment involving Stellenbosch University, a cell phone operator and a Provincial Department of Transport. The purpose of the initiative is to subject vehicles travelling on roads within the geographical area of the province to a proposed DBRUC fee structure. All monies collected (or rather simulated) should theoretically accrue to the Provincial Treasury and will solely be used for road projects within the provinces jurisdiction and for its mandate, thus a ring-fenced fund.

User interaction is facilitated through a website which is designed in such a way that it is easy to understand and use. On this platform volunteers for the experiments are canvassed and all information pertaining to the system usage are provided. The information includes aspects such as how the system works, legal issues, contact details, payment instructions, participant registration and a portal where individual road users can privately view their daily travel information including a private invoice.

The technology used for the in-vehicle hardware should be tamper proof, hidden in the vehicle but accessible for easy installation and removal. For this, an on-board diagnostics (OBD) port vehicle tracking device is suggested. This device through GPS and cellular technology is connected to a back-end system to run the necessary algorithms on the sourced data to clean, extract and convey information on the website. This include daily travel behaviour statistics including number of trips, trip duration, routes travelled, trip cost and most importantly the calculation of the DBRUC to be paid after a fuel levy rebate. Payment of the invoice can occur on a monthly or annual basis via banking apps or at provincial vehicle licensing and registration offices.

The road user charge applied must distinguish between vehicle type, road type, and time of travel. Furthermore, the calculation of the charge must be theoretically sound and financially feasible. The current fuel levy is not entirely based on theoretical road user costs principles but is rather a historic value increased yearly to reflect inflationary and budgetary demands. In turn the road user charge implemented by the OReGO system in the USA is merely a

conversion of the fuel tax (cost allocation study performed every two years) to a distance-based charge based on average vehicle fuel efficiency. This means older fuel inefficient vehicles essentially receive a rebate on their fuel tax already paid, while newer fuel efficient vehicles will be paying more making the payment for road use more equitable. This could be detrimental to a DBRUC initiative if it is based on a voluntary participant basis as most people who have something to gain will be the first to join the program. Another option is to employ a system based on average cost for each vehicle class given the vehicle class's combined distance travelled per annum (Freeman, 1982) to cover the road expenditure needed for the year (Department of Logistics, 2017). (Table 1).

Table 1: Alternative road user charge approaches (2017 values) (Department of Energy, 2017; Freeman, 1982)

	Current SA fuel tax: proper (2017)		Current SA fuel tax: combined levies (2017)		OReGo model*		Freeman model**
	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	
	(c/l)	(c/l)	(c/l)	(c/l)	(c/km)	(c/km)	(c/km)
Motorcars	315	300	492.33	467.01	33.9	32.1	58
LDV's – Bakkies	315	300	492.33	467.01	33.9	32.1	58
Minibuses	315	300	492.33	467.01	33.9	32.1	58
Buses	315	300	492.33	467.01	33.9	32.1	125
Trucks	315	300	492.33	467.01	33.9	32.1	146
Motorcycles	315	300	492.33	467.01	33.9	32.1	50
Other & Unknown	315	300	492.33	467.01	33.9	32.1	113

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

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

According to strict economic theory, an economic efficient road user charge should reflect short-run marginal social cost (MSC). However, in MSC pricing it is paramount to include the marginal infrastructure cost, marginal congestion cost, marginal accident cost and marginal environmental cost and then distinguish charges based on vehicle type, urban or rural environment, and road type used and travel conditions. Good quality data on road maintenance and management costs, the vehicle fleet (size and composition), vehicle emission and the costs of congestion is not readily available in South Africa. Cost allocation to specific vehicle types is therefore quite coarse (Korzhenevych et al., 2014). It is not possible, within the scope of this paper to derive MSC estimates for South Africa. Table 2 does not indicate what MSC should be in South Africa, it is merely an illustration of the ranges of MSC for road use in the EU and the comparative South African values, based on Purchasing Power Parity (PPP).

Table 2: MSC calculation approach (2017 values)
(Korzhenevych et al., 2014; Doll & Essen, 2008)

	Region	Road type	Free flow	Near capacity	Over capacity
			(c/km)	(c/km)	(c/km)
Car	Metropolitan	Motorway	0.00	244.96	563.04
		Main roads	8.55	1 293.18	1 658.72
		Other roads	22.79	1 459.33	2 219.86
	Urban	Main roads	5.70	445.30	694.06
		Other roads	22.79	1 276.09	2 109.72
	Rural	Motorway	0.00	122.48	281.52
		Main roads	3.80	167.62	555.42
		Other roads	1.90	384.54	1 274.19
Rigid truck	Metropolitan	Motorway	0.00	465.43	1 069.77
		Main roads	16.24	2 457.04	3 151.57
		Other roads	43.30	2 772.74	4 217.73
	Urban	Main roads	10.82	846.07	1 318.72
		Other roads	43.30	2 424.57	4 008.47
	Rural	Motorway	0.00	232.72	534.88
		Main roads	7.22	318.47	1 055.29
		Other roads	3.61	730.62	2 420.96
Articulated truck	Metropolitan	Motorway	0.00	710.39	1 632.80
		Main roads	24.78	3 750.22	4 810.30
		Other roads	66.08	4 232.07	6 437.59
	Urban	Main roads	16.52	1 291.37	2 012.78
		Other roads	66.08	3 700.65	6 118.19
	Rural	Motorway	0.00	355.20	816.40
		Main roads	11.01	486.09	1 610.70
		Other roads	5.51	1 115.15	3 695.15
Bus	Metropolitan	Motorway	0.00	612.41	1 407.59
		Main roads	21.36	3 232.94	4 146.81
		Other roads	56.97	3 648.34	5 549.65
	Urban	Main roads	14.24	1 113.25	1 735.16
		Other roads	56.97	3 190.22	5 274.30
	Rural	Motorway	0.00	306.20	703.79
		Main roads	9.49	419.04	1 388.54
		Other roads	4.75	961.34	3 185.47

Table 2 show how road user charges are differentiated by location, time of day and vehicle characteristics, and specifically the importance of congestion on road user charges.

4. CASE STUDY

In May 2017 an invitation to take part in a voluntarily road user charging study was circulated to staff of a large employer. The research was undertaken in the Cape Winelands District Municipality and the City of Cape Town, Western Cape. A screening process followed to verify that the 18 participants used their vehicles on a regular basis within the two municipal areas that these participants were the registered owners of the vehicles to be tracked, their vehicles were manufactured after 1996 and the participants were willing to provide consent for their daily vehicle activity to be recorded and analysed.

Arrangements were made with each participant to install a removable OBD 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 answer any questions which the participants may have. It is entirely possible that devices could in the future be mailed to the participants for self-installation as is done in the USA and the EU. 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 was active for a four week period. There was no active participation 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 from whom the tracking units was bought. The tracking data consisted of information about vehicle travel behaviour that was recorded on average every 10 seconds, which included speed, the time and the vehicle's location. The CSV files was imported into a Microsoft Excel database for analysis. Algorithms were 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 upon (freeway, main road and other). Given the speed (used to determine road capacity), distance, time and road travelled upon, each section of the vehicle's travel behaviour (the distance between two subsequent recorded data points) were subject to a particular road user charge being levied depending on the charging approach employed and calculation of the set fee.

Table 1 shows the four road use charges used in the experiment. The first charge is the conventional fuel levy and was calculated simply by multiplying the fuel levy with the amount of fuel used (the latter determined by the fuel efficiency of each individual vehicle in the study). The other three approaches charge vehicles according to the distance they travelled. This includes the OReGO approach where the conventional fuel levy, per litre, is converted to a kilometre value based on the average fuel efficiency of all vehicles in the country. The third charge was the short-run marginal cost approach which includes the cost of externalities (congestion, accident and environmental) and the cost of infrastructure (maintenance and operation). The final charge was termed the Freeman model which was based on average costs of annual road expenditure. Individual travel data was made available to the participants via the online website showing an infographic of their travel behaviour and a hypothetical invoice for road use the period under consideration.

5. FINDINGS

The results of the 4 week road use charging experiment is presented in Table 3. The participants' distance driven for the tracking period varied substantially, mainly due to different distance between home and work 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 an income of R 7722.03 (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 converts the fuel levy as mentioned above into a kilometre rate based on an average fuel economy of 6.9 l / 100 km which is multiplied with each participants' distance travelled. Short-run marginal social cost, which includes marginal infrastructure, emission, congestion and accident cost delivered the most revenue. This is due to the bulk of travelling taking place in the congested peak hours and on urban roads. Freeman's approach uses an average cost per kilometre and is derived from the annual expenditure of R 117 billion on the road sector (2017), allocated to different vehicles types and multiplied with the distance. The approached delivered an income of R13 497.47.

Table 3: Envisaged revenue to be collected by different charging approach

Participant #	Kms driven	1 Fuel Levy	2 OReGO' model	3 Short run marginal social cost	4 Freeman's model
Participant 1	1 019.20	R575.93	R 404.58	R 2 263.63	R 587.20
Participant 2	1 156.10	R 458.92	R 458.92	R 1 063.85	R 666.07
Participant 3	1 132.43	R 451.60	R 473.90	R 501.60	R 652.44
Participant 4	1 202.55	R 367.07	R 503.24	R 2 934.90	R 692.84
Participant 5	3 013.53	R 786.34	R 1 261.10	R 4 810.60	R 1 736.21
Participant 6	1 036.22	R 336.71	R 433.64	R 2 052.51	R 597.01
Participant 7	661.55	R 373.83	R 262.61	R 393.87	R 381.15
Participant 8	812.92	R 248.14	R 340.19	R 393.87	R 468.35
Participant 9	917.65	R 244.27	R 364.27	R 3153.67	R 528.69
Participant 10	786.71	R 304.94	R 312.29	R 2 680.14	R 453.25
Participant 11	2 460.50	R 702.60	R 1 029.67	R 1 914.68	R 1 417.59
Participant 12	423.20	R 239.14	R 167.99	R 1 123.07	R 243.82
Participant 13	2 222.13	R 809.58	R 929.92	R 2 989.43	R 1 280.26
Participant 14	789.11	R 240.87	R 330.23	R 534.87	R 454.64
Participant 15	1 195.77	R 365.00	R 500.41	R 535.96	R 688.93
Participant 16	1 005.92	R 292.20	R 420.96	R 2 431.24	R 579.55
Participant 17	2 064.79	R 548.94	R 864.07	R 5 267.37	R 1 189.60
Participant 18	1 527.21	R 375.95	R 639.11	R 441.25	R 879.88
Total	23 427.49	R 7 722.03	R 9 697.10	R 35 486.52	R 13 497.47

The fuel levy delivered the least income from the fours 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 kilometre based on an average vehicle fuel efficiency, a 26% increase in revenue can be generated compared to the fuel levy. The increase in revenue can be attributed to the fact that all vehicles are now paying equally for road use, whereby those with fuel efficient vehicles who did not pay enough for their road use now are, and conversely those who paid too much due to owning fuel inefficient vehicles now will be paying less. This is also interesting as it shows what the impact of fuel efficiency is. Freeman's approach in turn delivers close to double the revenue, because it factors in all cost needed to fund the road sector for the specific year and not just a historic value adjusted to inflation and budgetary needs. 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 revealed that with the OReGO method, the driver would have paid a lesser road user charge for the month compared with the fuel levy. This is because the participant's vehicle (Mitsubishi Pajero 3.2D) is not as fuel efficient as some of the other vehicles and is above the average vehicle fuel efficiency of 6.9 l/100kms. Due to the vehicles fuel efficiency, the participant is already almost paying the vehicles average share required to fund the annual road infrastructure expenditure, if the charge based on Freeman's model and the fuel levy is compared. Internalising his/her 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 kilometres but using a more fuel efficient vehicle compared to the average and thus paying less fuel levy. As a result the OReGO method would see the participant paying almost double, making the payments of road user cost fairer across all road users. This indicates a possible flaw whereby the OReGO method at a flat fee will secure income but at the expense of motivating behavioural change to less environmental polluting vehicles. The participant would still need to pay more according to Freeman's model but in term 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 2).

Accordingly older, less fuel efficient vehicles will benefit from a more equitable OReGO model approach if the fuel levy was converted to kilometre measurement units rather than litres, and new, more fuel efficient vehicles will benefit more from the conventional fuel levy. The former two charging models will maximise electric and hybrid vehicles' road user benefit and thus it would be better to charge all vehicles per distance travelled through a method adopting MSC in its charge or the Freeman model at average cost per distance.

6. SYSTEM COST: AN INTERIM DISCUSSION

A key system requirement is that implementation cost should be acceptable from the perspective of the implementing authority and the users. The various mechanisms currently employed to generate revenue from road users in South Africa all have different collection cost. Fuel levies, including the general fuel levy and the road accident fund levy, generate 70% of the total direct road user income collected per annum at a very low cost of collection of less than one percent (both locally and internationally) (Bahl, 1992; Balducci et al., 2011; Department of Logistics, 2017; Duvenage, 2015). Toll roads generate a further 10% of direct road user income with a collection cost of around 30% (OUTA, 2018; Duvenage, 2015). Thirdly, mechanisms that stem from regulation which include the issuing of vehicle licence fees, fines and permits contribute 18% to the total direct road user income while collection costs can amount to 50% (National Treasury, 2014). Lastly CO^2 emission tax, contributes 2 % to direct road user income with a cost of collection of one percent (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). This is far less than the collection cost of tolling. The advancement of technology used by DBRUC would further reduce the collection cost. Estimating the cost to revenue collected ratio for the DRiVE initiative, if extrapolated for a 1 year period, showed a ratio of 9%.

7. CONCLUSIONS

The paper discussed a pilot study to assess the potential road user income from a voluntary distance-based road user charge system. A comparison was made between using four different charging approaches on each participant's travel behaviour, which included the current fuel levy tax used in South Africa, the fee structure used in the USA road user charge experiments and 2 theoretical fee structures. The pilot results shows that for the study area and participants, the conventional fuel levy delivered the smallest income whiles the MRC

approach delivered the largest income This can be attributed to the congestion costs element associated with the MRC and 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 social marginal fare structure that incorporates infrastructure, accident, environment and congestion cost. An alternative is to use a quasi-system to cover only the funding gap not covered through existing cost recovery methods. DBRUC, although incurring more implementation and operating cost than the current fuel levy system, is easy to use and understand; would provide greater funding security to government; and information regarding cost to infrastructure providers and users to make informed decisions.

Recommendations

The South African government, on all three levels, and road users need to be aware of the exact cost that is needed to provide, maintain and expand our roads to ensure a functioning road network. This should further be delegated to the micro level where each vehicle owner knows his/her exact cost imposed on the road network, not only in terms of road wear or capacity needed, but also in terms of external cost pertaining to accidents, environmental pollution from operating a vehicle and congestion, through an exact user charge. Active engagement in research is needed to assess roads users' opinion and acceptance about a road user charge concept. 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 work

Scaling issues still exist to test the proposed cost recovery method in terms of operability, implementation and running cost, ethical issues pertaining to road user's perception of the system and acceptability, and lastly government policy. Future experiments will include at least 100 vehicles where behaviour responses will be tested, and the model calibrated with South African data (specifically the cost of congestion). It would be interesting to be able to compare the South African distance-based road user charge system and the users experience and acceptance of using the system with the Oregon and California road user charge experiments in the USA. These experiments are the benchmark for an all-inclusive DBRUC system that incorporates all types of vehicles.

REFERENCES

ASFiNAG, 2017. Heavy goods vehicles road user charging. Available at: http://www.asfinag.at/toll [Accessed June 5, 2017].

Bahl, R., 1992. *The Administration of Road User Taxes in Developing Countries* 986th ed., World Bank Publications.

Balducci, P. et al., 2011. *Cost of Alternative Revenue-Generation Systems*, Washington.

Department of Energy, 2017. Fuel levy price. Available at: http://www.energy.gov.za/files/esources/petroleum/petroleum_arch.html
.

Department of Logistics, 2017. *Funding for Roads in South Africa: Understanding the principles of fair and efficient road user charges*, Stellenbosch.

Doll, C. & Essen, H., 2008. Road Infrastructure cost and revenue in Europe.

Duvenage, W., 2015. Fuel levy is the best solution. Here's why. *Daily Maverick*. Available at: https://www.dailymaverick.co.za/opinionista/2015-05-29-fuel-levy-is-the-best-solution.-heres-why.../#.WmWWB6iWbIU [Accessed January 22, 2018].

Freeman, P.N., 1982. *The recovert of costs from road users in South Africa Part III: Towards a practical solution*
.

HU-GO, 2017. Distance based toll for heavy goods vehicles. Available at: https://www.hu-go.hu/ [Accessed July 20, 605]
.

Kirk, R.S. & Levinson, M., 2016. *Mileage - Based Road User Charges*.

Korzhenevych, A. et al., 2014. Update on the Handbook on External Cost of Transportation. Final Report
.

MYTOCZ, 2017. Heavy goods vehicles road user charging. Available at: http://www.mytocz.eu/en/index.html [Accessed June 5, 2017]
.

National Treasury, 2014. Provincial budget. Available at: http://www.treasury.gov.za/documents/provincial budget/2014/4. Estimates of Prov Rev and Exp/Default.aspx [Accessed November 30, 2016].

New Mexico Taxation and revenue department, 2017. Weight distance tax for heavy vehicles. Available at: http://www.mvd.newmexico.gov/weight-distance.aspx [Accessed June 5, 2017]
.

OUTA, 2018. The fuel levy. *E-toll campaign*. Available at: https://www.outa.co.za/e-tolls-campaign/4362-2/ [Accessed January 22, 2018]
.

Van Rensburg, J. & Krygsman, S., 2016. A kilomtre-based road user charge system: Proof of concept study. In *35th Annual South African Transport Conference - Transport - a catalyst for socio-economic growth and development opportunities to improve quality of life*
.

Van Rensburg, J. & Krygsman, S., 2015. Running Dry: Assessing the fuel levy as a long term economically effiecient road use fund. In *34th Annual South African Transport Conference - Transport: Working together to deliver*. Pretoria. Available at: http://www.satc.org.za/.

SARS, 2016. Tax statistics for 2016. Available at: http://www.sars.gov.za/Media/MediaReleases/Pages/29-November-2016---Tax-Statistics-for-2016.aspx [Accessed January 22, 2018].

State of California, 2017. California Road Charge Pilot Program. Available at: https://www.californiaroadchargepilot.com/ [Accessed June 2, 2017].

State of Oregon, 2017. OReGO. Available at: http://www.myorego.org/ [Accessed June 5, 2017].

Viapass, 2017. Heavy goods vehciles road user charging. Available at: http://www.viapass.be/en/ [Accessed June 5, 2017].