DISRUPTIVE TRANSPORT TECHNOLOGIES: FORECASTING THE IMPACT ON ROAD-GENERATED REVENUES IN SOUTH AFRICA

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ABSTRACT

Disruptive transport technologies have been present since the industrial revolution, creating a future that was not directly foreseen, for instance, the invention of the steam locomotive that replaced horse-drawn carts. Modern technological innovations in the transport sector, such as more fuel-efficient vehicles, may have an immediate impact on the amount of road-generated revenue collected through countries' road funding frameworks. This paper examines the extent to which disruptive transport technologies may impact South Africa's ability to secure funding for roads in the future. Various road user cost recovery methods' revenue potential are forecast up to the year 2030 which aligns with the National Development Plan's horizon year, taking into account the impact of modern-day technological and resulting societal trends that include *inter alia* improved fuel efficiency, the introduction of electric vehicles, the usage of e-hailing services and policy adoption of greener vehicle technologies. Trend line forecasting and scenario writing are incorporated into this analysis, sourcing data from various government department budgets and research reports. It was found that these technological advancements, although having an impact on road-generated revenue, will rather be incremental in the short to medium terms, and not disruptive as a rule, as companies normally adopt and standardise the latest innovation in the industry over time. The article concludes by proposing that a distance-based road user charging system might be less susceptible to any incremental or disruptive technologies and can be a good mechanism to possibly use in order to apply the user pay principle.

1. INTRODUCTION

Innovative technologies change the way the world works and is normally observed in two ways (Hacklin, Raurich and Marxt, 2004). Firstly, from a disruptive manner through the introduction of a new creative product or way of delivering the product that is rapidly making the old product redundant. This will create a change in the future that does not exist in the current setting, such as the advancement from powered aircraft to commercial (jet-powered) aviation that made intercontinental passenger steam liners less desirable and used. Secondly, changes can be incremental by providing more value to the customer over time with the same product or service through innovation or improvement. Herewith industry adopts the latest innovation to make a product or service standardised in the short to medium terms such as Wi-Fi internet 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 *et al.*, 2013). This outcome is seen as changing the way travellers commute in the future, but more worrisome from a governmental perspective is the effect it may have on road revenues collected from road users to aid in the funding of a country's road network. Income from South African road users and vehicle owners surpassed R100 billion per annum since 2014 and fluctuates based on the vehicle fleet and magnitude of road use (Department of Logistics, 2017). Although substantial amounts, this 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. As public infrastructure is subject to economic evaluation and not financial evaluation a certain amount of funding shortfall can be expected.

The National Development Plan (NDP) aims to eliminate poverty and reduce inequality in South Africa by the year 2030 (National Planning Commission, 2009). It is, however unknown to what extent disruptive transport technologies may impact the country's future ability to recover the road user cost in a fair and effective manner in order to secure funding and financing for government to address its development goals through investment, especially in the road sector. This paper examines the extent to which disruptive transport technologies may impact South Africa's ability to secure funding for roads using current charging mechanisms. In South Africa, research in this regard is not available.

The paper is structured in five sections. Following the introduction, Section 2 provides a brief review of the impacts and implications of disruptive transport technologies from an international perspective. Section 3 describes envisaged disruptive technological and societal trends that may have an impact on South Africa's road user cost recovery methods. This is followed by a forecast of South Africa's road user cost recovery methods' revenue potential taking into consideration the existence and emergence of transportation technologies and resulting societal trends. The paper concludes with a discussion on how the government can use these emerging technologies as a way to implement a user-pay principle policy for the road sector through distance-based road user charging.

2. IMPACTS AND IMPLICATIONS OF DISRUPTIVE TRANSPORT TECHNOLOGIES FROM AN INTERNATIONAL PERSPECTIVE

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 envisaged results of the new technology is greater funding uncertainty (Wachs and Moore, 2018). This was made apparent in a discussion session during the Transportation Research Board conference on surface transportation finance in California. Martin Wachs of RAND stated that the prediction window to accurately estimate future road revenues were 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 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 United States could result in a change in commuter travel behaviour reducing the user base of the conventional road charging methods (Clewlow and Mishra, 2017). It was found through a survey of over 4000 respondents undertaken in seven major metropolitan areas in the

United States that 9% of e-haling users sold their vehicles and that depending on the public transport service under review, e-hailing services could have a substitute or complementary effect, with an average reduction of 6% in public transport services noted.

Similarly, San Francisco in the US, already experienced a 10% reduction in parking revenue over the past two years, as where Portland experienced a 10% - 25% reduction in total transport revenues in municipal budgets (Larco, 2018). The author also noted that telecommunication may substitute travel leading to less parking space, resulting in greater urbanisation in the place of unused parking lots. An Australian study in turn suggests that disruptive transport technologies may result in the reduction of the revenue collected by governments from among other the fuel levy, parking fees and congestion charges. This may be due to the increased usage of e-hailing services and electric vehicles which 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 it provides such as parking, rental cars and ground transportation. If this latter income 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 potential loss of air service demand.

Conversely, disruptive technologies are not all harmful. As it may have a negative impact on the activities of an economic sector or business from one perspective it may have advantages from another. Herewith referring to 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 similarly could lead to less emissions at ground level, and consequent air quality and health gains (Transportation Policy Research Centre, 2016).

3. IDENTIFYING DISRUPTIVE TRENDS AFFECTING CURRENT ROAD USER COST RECOVERY METHODS IN SOUTH AFRICA

The government collects revenue from vehicle owners and road users by using 12 road user cost recovery methods (presented in Table 1), with direct road users charges and mainly the fuel levy adhering to adequacy, equity, efficiency and simplicity principles (Archer, 2018). The amount of revenue that a road user charge or levy can generate 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 user 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 user cost recovery methods can be grouped in three categories. The first category is fuel-based recovery, which consists of six methods 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 that takes effect on an annual basis or when a vehicle is purchased or new tyres are bought, which accounts for 9% of all road-generated revenue. The final category is user-based which entails a further three recovery methods 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 need for income or inflationary increases. In turn, the measuring unit component (quantity used) may be affected by technological advancements and social activities (trends) which may have a close relation or is 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 kilometres travelled, the use of greener vehicle technologies and vehicle part that lasts longer, the decrease in vehicle ownership and the lack of user payment compliance (see Table 1).

Table 1: South Africa's road user cost recovery methods and affecting trends

				Components that determine individual road user cost recovery methods' revenue		Trends impacting cost and measuring unit components		
Category % of road-generated revenue	**Method % of road-generated revenue**	**Road user cost recovery Category**	**Road user 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**	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/road 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. FORECASTING THE IMPACT OF DISRUPTIVE TECHNOLOGICAL AND SOCIETAL TRENDS ON ROAD-GENERATED REVENUES

Using trend line forecasting, South Africa's road user cost recovery methods' future revenue was forecast up to the year 2030. Data was sourced from numerous government departments and road related state-owned entities financial reports from the year 2000 to 2014 (see sources in Table 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. This data was used to create the trend line forecast coefficients or rather to estimate the intercept and slope of the trend line forecast equation for each road user cost recovery method, and then apply the trend line forecast equation for each specific method to create a projection from 2015 to 2030. The average absolute percentage error in the fuel-based recovery methods' forecast was 7%, vehicle-based recovery methods' forecast was 12% and the user-based recovery methods' forecast was 8%. This possible forecast error may be the result of large increases in revenue between consecutive years of selected road user cost recovery methods as a result of increased fee or charge adjustments or more effective implementation of the respective method since 2000 (see Table 2).

Table 2: South Africa's road user cost recovery methods' revenue forecast (Rand)

'000 000		Actual	Projection			
Category	Road user cost recovery method	2010	2015	2020	2025	2030
Fuel-based	Fuel levy	32 837	64 811	83 919	109 779	135 639
	Road Accident Fund	14 702	40 425	51 007	69 962	88 918
	Custom and excise levy	817	1 050	1 049	1 153	1 257
	Demand Side Management Levy	51	263	807	1 141	1 474
	IP Marker levy	1	1	1	1	1
	Petroleum Products Levy (Pipeline)	31	39	72	96	119
Vehicle-based	License fees	5 057	7 949	10 646	13 343	16 040
	CO_2 emissions	625	2 067	3 135	4 203	16 040
	Tyre Levy	0	0	397	449	502
User-based	Fines/fees and permits	9 011	11 852	13 452	15 051	16 651
	Toll fees	2 073	4 168	6 703	9 238	11 772
	Toll fees concessions	3 987	6 337	8 603	10 869	13 135
	Total road-generated revenue	69 195	138 964	179 796	235 290	301 554

(Sources: Road Accident Fund, 2014; SAPIA, 2014; Department of Energy, 2013; National Treasury, 2014d; National Treasury, 2014c; National Treasury, 2015; National Treasury, 2014b; Statistics South Africa, 2014; Statistics South Africa, 2016; International Transport Forum, 2015; Arrivealive, 2016; Bakwena N1N4 toll, 2016; Trans African Concession, 2016; N3TC, 2016; SANRAL, 2016)

Following the revenue forecast the assessment of the impact that the various trends may hold, as mentioned in section 3, were undertaken and assumed the emergence of these trends since the year 2015. These trends were projected through hypothetical scenario writing on the forecasted revenues of the road cost recovery methods calculated in Table 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 one measuring unit and multiplying this value with the number of measuring units lost or affected due to the trend.

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 period of 1990 and 2011 due to technological advancements (European Environment Agency, 2015) which was confirmed by the United States Energy Information Administration (US 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 United States, and thus using European and American data can only provide a partial indication of what might transpire is South Africa. Applying the efficiency improvement to the revenue forecast showed revenue loss if assumed that all new vehicles bought in South Africa from 2015 follows this efficiency, but slowly increases as consecutive years' new vehicles boast further fuel efficiency improvements (see Table 3).

Table 3: Revenue loss due to *vehicle fuel efficiency improvement* (Rand)

'000 000		Actual	Projection with trends			
Category	Road user cost recovery method	2010	2015	2020	2025	2030
Fuel-based	Fuel levy	0	19	447	1 615	3 631
	Road Accident Fund	0	12	272	1 029	2 380
	Custom and excise levy	0	<1	5	16	33
	Demand Side Management Levy	0	<1	4	16	39
	IP Marker levy	0	<1	<1	<1	<1
	Petroleum Products Levy (Pipeline)	0	<1	<1	1	3
	Total revenue loss	0	31	730	2 679	6 088
	Total revenue % loss	0	-0.02%	-0.40%	-1.14%	-2.02%

It is envisaged that the share in bio-fuel sales in relation to total fossil fuel sales will be 2% from 2015 (SouthAfrica.info, 2013). This shows a revenue loss of less than 2% for the foreseeable future for all fuel-based road user cost recovery methods (see Table 4).

Table 4: Revenue loss due to *biofuel penetration* (Rand)

'000 000		Actual	Projection with trends			
Category	Road user cost recovery method	2010	2015	2020	2025	2030
Fuel-based	Fuel levy	0	1 296	1 678	2 195	2 712
	Road Accident Fund	0	808	1 020	1 399	1 778
	Custom and excise levy	0	21	20	23	25
	Demand Side Management Levy	0	5	16	22	29
	IP Marker levy	0	<1	<1	<1	<1
	Petroleum Products Levy (Pipeline)	0	<1	1	1	2
	Total revenue loss	0	2 131	2 737	3 642	4 548
	Total revenue % loss	0	-1.53%	-1.52%	-1.55%	-1.51%

Hybrid vehicle technologies can increase fuel efficiency (laboratory-based) up to 35% (National Research Council, 2015). Examples of such and related technologies include stop-start systems that reduce wasted fuel from idling, regenerative braking that can recover and reuse small amounts of energy lost from braking, and larger electric motors and batteries to reduce fuel use by using electricity as a power source. These technological advancements have and will continue to decrease a vehicle's 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 (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 2030. But surely this trend 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 (see Table 5).

Table 5: Revenue loss due to *electric vehicle penetration* (Rand)

'000 000		Actual	Projection with trends			
Category	Road user cost recovery method	2010	2015	2020	2025	2030
Fuel-based	Fuel levy	0	9	62	132	213
	Road Accident Fund	0	5	38	84	140
	Custom and excise levy	0	<1	<1	1	1
	Demand Side Management Levy	0	<1	<1	1	2
	IP Marker levy	0	<1	<1	<1	<1
	Petroleum Products Levy (Pipeline)	0	<1	<1	<1	<1
	Total revenue loss	0	15	102	220	358
	Total revenue % loss	0	<-0.00%	<-0.00%	<-0.00%	<-0.00%

The total vehicle kilometres travelled by the registered vehicle population increased by 38.5% at an average annual rate of 3.7% between the periods 2003 to 2012 (Van Rensburg and Krygsman, 2015). During the same period, the total registered vehicle population of South Africa increased by 47.2% at an average annual growth rate of 4.4%. Although this data needs to be updated, it showed that within this decade on average vehicle kilometres travelled per vehicle in South Africa decreased at a rate of 110 kilometres per year. This trend when projected also shows marginal revenue losses (see Table 6).

Table 6: Revenue loss due to *decreased distance travelled* (Rand)

'000 000		Actual	Projection with trends			
Category	Road user cost recovery method	2010	2015	2020	2025	2030
Fuel-based	Fuel levy	0	737	770	817	835
	Road Accident Fund	0	459	468	520	547
	Custom and excise levy	0	11	9	8	7
	Demand Side Management Levy	0	2	7	8	9
	IP Marker levy	0	<1	<1	<1	<1
	Petroleum Products Levy (Pipeline)	0	<1	<1	<1	<1
User-based	Toll fees	0	47	61	68	72
	Toll fees concessions	0	72	78	80	80
	Total revenue loss	0	1 332	1 396	1 505	1 554
	Total revenue % loss	0	-0.96%	-0.78%	-0.64%	-0.52%

Driving an electric vehicle (EV) rather than a conventional fossil fuel-powered vehicle effectively may not reduce global-scale CO_2 emissions. Charging EVs on electricity grids that rely heavily on fossil fuel energy sources (coal) may, in fact, increases CO_2 emissions. A negligible 4.9% CO_2 emissions difference EV used in Germany showed a possible reduction of CO_2 emissions of just 8.7% compared to fossil fuel vehicles (Richard, 2018). As international standards are set with regard to curbing global warming and initiatives such as the independently-produced renewable energy program is introduced, the revenue loss of this trend might decrease, but would be marginal at best for the coming years as this will only be required to be implemented in new vehicles (see Table 7).

Table 7: Revenue loss due to *greener vehicle technologies* (Rand)

'000 000		Actual	Projection with trends			
Category	Road user cost recovery method	2010	2015	2020	2025	2030
Vehicle-based	CO_2 emissions	0	185	280	376	1 436
	Total revenue loss	0	185	280	376	1 436
	Total revenue % loss	0	-0.13%	-0.16%	-0.16%	-0.48%

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 and on average get 30 000 kilometres out of front tyres on a front-wheel-drive vehicle, and double that for the rear tyres. 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 8).

Table 8: Revenue loss due to *vehicle parts usage efficiency* (Rand)

'000 000		Actual	Projection with trends			
Category	Road user cost recovery method	2010	2015	2020	2025	2030
Vehicle-based	Tyre Levy	0	0	79	89	100
	Total revenue loss	0	0	79	89	100
	Total revenue % loss	0	0	-0.04%	-0.04%	-0.03%

Our evolving relationship with cars has been largely driven by e-hailing companies, and this has given them a significant influence on drivers, cities and the industry as a whole. A recent report from Lyft claimed that the company provided 375.5 million rides in 2017 and that 250 000 passengers got rid of their cars that year specifically, in the United States alone, because of e-hailing services (Hallgren, 2018). This could possibly happen in South Africa with the increased usage of Uber, but with the majority of vehicle owners being middle 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 9).

Table 9: Revenue loss due to *decreased vehicle ownership* (Rand)

'000 000		Actual	Projection with trends			
Category	Road user cost recovery method	2010	2015	2020	2025	2030
Fuel-based	Fuel levy	0	294	2 116	4 727	7 948
	Road Accident Fund	0	183	1 286	3 012	5 210
	Custom and excise levy	0	4	26	49	73
	Demand Side Management Levy	0	1	20	49	86
	IP Marker levy	0	<1	<1	<1	<1
	Petroleum Products Levy (Pipeline)	0	<1	1	4	7
Vehicle-based	License fees	0	188	1 325	2 691	4 216
	CO_2 emissions	0	1 649	2 562	3 521	13 783
	Tyre Levy	0	0	8	8	8
User-based	Fines/fees and permits	0	280	279	275	273
	Toll fees	0	98	139	169	193
	Toll fees concessions	0	150	178	199	215
	Total revenue loss	0	2 851	7 944	14 708	32 016
	Total revenue % loss	0	-2.05%	-4.42%	-6.25%	-10.62%

A major concern is that it is estimated that some four-million vehicles on SA roads are unregistered (ITSSA, 2008). It must be noted that it is uncertain if 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, of the more than 1.8bn invoices that were issued with the advent of the e-toll system, more than 1.3bn (more than 71%) were unpaid (Peyper, 2017). Although traffic fines and toll system payments are not directly comparable, the above strives 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, and therefore essentially there is a breakdown in trust between the user and government. Many South Africans pay transport-based accounts such as vehicle license fees and traffic fines regularly, so it's safer to say that around 50% of all road users are non-compliant. This shows lack of user compliance as the second most concerning factor that may have an impact on road revenues (-4.16% by 2030) after a decrease in vehicle ownership as shown above (-10.62% by 2030) (see Table 10).

Table 10: Revenue loss due to *lack of user compliance* (Rand)

'000 000		Actual	Projection with trends			
Category	Road user cost recovery method	2010	2015	2020	2025	2030
Vehicle-based	License fees	0	3 014	3 533	3 914	4 216
User-based	Fines/fees and permits	0	5 926	6 726	7 525	8 325
	Total revenue loss	0	8 940	10 259	11 440	12 541
	Total revenue % loss	0	-6.43%	-5.71%	-4.86%	-4.16%

Assuming all the listed trends and that the associated impact was to take effect from the year 2015, it can be seen 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 or mass electric vehicle adoption, up to the 2030 horizon, technological and societal trends will only have an incremental impact on road-generated revenues every five years and not be as disruptive as thought (see Table 11).

Table 11: South Africa's road user cost recovery methods' total revenue loss due to disruptive technological and societal trends (Rand)

'000 000		Actual	Projection with trends			
Category	Road user cost recovery method	2010	2015	2020	2025	2030
Fuel-based	Fuel levy	0	2 356	5 076	9 487	15 341
	Road Accident Fund	0	1 469	3 085	6 046	10 057
	Custom and excise levy	0	38	63	99	142
	Demand Side Management Levy	0	9	48	98	166
	IP Marker levy	0	<1	<1	<1	<1
	Petroleum Products Levy (Pipeline)	0	1	4	8	13
	Total revenue loss	0	3 875	8 278	15 741	25 722
	Total revenue % loss	0	-2.79%	-4.60%	-6.69%	-8.53%
Vehicle-based	License fees	0	3 202	4 858	6 605	8 432
	CO_2 emissions	0	1 834	2 843	3 897	15 220
	Tyre Levy	0	0	87	98	108
	Total revenue loss	0	5 037	7 789	10 601	23 760
	Total revenue % loss	0	-3.62%	-4.33%	-4.51%	-7.88%
User-based	Fines/fees and permits	0	6 207	7 005	7 801	8 599
	Toll fees	0	146	200	238	265
	Toll fees concessions	0	222	257	280	296
	Total revenue loss	0	6 575	7 463	8 320	9 161
	Total revenue % loss	0	-4.73%	-4.15%	-3.54%	-3.04%
	Total road-generated revenue loss due to technological and societal trends	0	15 488	23 452	34 663	58 644
	Total road-generated revenue % loss due to technological and societal trends	0	-11.15%	-13.09%	-14.73%	-19.45%

5. CONCLUSION

The paper discussed the potential impact that disruptive transport technologies may have on road-generated revenues in South Africa. It was argued that the current mechanisms used by the government to tax road users for road use and vehicle ownership are not immune to technological and societal trends. This paper commenced by presenting at a strategic level in section 2, 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 United States, and it 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 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. But the shortfall of 19% in 2030 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. The results further show that full-scale adoption of especially electric vehicles and reduced vehicle ownership due to e-hailing services will have a profound effect on road-generated revenues, especially from fuel-based cost recovery methods. Future road-generated revenue projections will become inaccurate and have a detrimental effect on budget planning if a great deal of attention is not given to the possible impact that disruptive transport technologies may hold. Government departments and road related state-owned entities tasked with collecting fees and charges from road users have to be aware that disruptive technologies are present and more will emerge in the foreseeable future. It must, therefore, ensure that contingency plans for collecting road-generated revenue is in place so not to become victims of the disruption.

It is recommended not to see the new emerging technologies as a barrier that will complicate and reduce the amount of future road-generated revenues, but rather as a way 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 of benefit is the use of location-aware technologies, such as vehicle tracking GPS devices, to charge vehicles based on the distance that they travel which will be resistant to many technological and societal trends and can combine many of the existing road cost recovery methods revenue potential through a single road usage fee.

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