INNOVATIONS IN FINANCING LAND TRANSPORT

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ABSTRACT

The environmental impact of land transport has been widely explored in South Africa; however, implementation of mitigation is still lagging behind. Implementation of strategies requires funding. The National Revenue Fund (NRF) provides financial support for all government programs, including land transport. The allocation of funds for road infrastructure, public transportation, and transport-related research competes with other demands for service delivery funding.

Section 28 of the National Land Transport Act allows municipalities to impose user charges on specific categories of motor vehicles as the need arises. Vehicle licensing can be used as one of the revenue generating methods by government. The underlying principles of vehicle licensing primarily aim to enhance road safety and, secondarily, to mitigate the carbon footprint of motor vehicles. Methods for implementing user charges are not explicitly outlined and therefore, allowing for flexibility and innovation in financing land transport.

This study explores innovative ways to charge fees for the use of private transportation within Low Emission Zones (LEZs) and/or congested routes through a proficient vehicle licencing system, to reduce greenhouse gases that have a negative impact on the quality of the air. This paper aims to present the approach used to develop the fee charging technique with the use of existing vehicle data.

1. INTRODUCTION

Land transportation constitutes and will continue to serve as the cornerstone of South Africa's economy. The maintenance and enhancement of land transport infrastructure and services necessitate ongoing and substantial financial investment, traditionally derived from the national treasury. However, mounting pressure on the national budget to allocate resources for various vital national initiatives has resulted in insufficient funding allocation for land transport. The adverse repercussions stemming from inadequate land transport infrastructure and services reverberate across society, impacting both individuals and the broader economy. Therefore, the exploration of innovative financing avenues for sustainable land transport remains of paramount importance. This underscores the criticality of devising innovative funding models dedicated to supporting environmentally friendly transportation systems for the attainment of sustainable development goals.

Furthermore, land transport inherently poses a significant environmental burden as a major source of atmospheric pollution and a contributor to climate change. The Cambridge dictionary defines a Low Emission Zone (LEZ) as an area of a city that vehicles which produce more than a low level of harmful emissions (waste gases) must pay to enter. According to Institute for Transportation and Development Policy (ITDP)'s definition, a low

emissions or car-free zone is a zone that restricts the use of polluting vehicles through priced and non-priced strategies. Priced LEZs restrict vehicles by charging drivers a fee to enter. A congestion charging zone (CCZ) is an area where vehicles must pay a fee to enter during specific times, aiming to reduce traffic congestion and improve air quality. Both Congestion Charge Zones (CCZs) and Low Emission Zones (LEZs) are mechanisms implemented by cities to reduce congestion and emissions, thus improving travel times and air quality. CCZs typically charge vehicles for entering a designated area during certain times of the day, while LEZs restrict entry to only low-emission vehicles meeting specific environmental standards. Both aim to alleviate traffic congestion and reduce pollution levels in urban areas. There are no LEZs and CCZs that have been identified in South Africa.

Health and environmental costs of local air pollution and greenhouse gas emissions are increasing and enhanced by stop-and-go traffic (Lindsey, 2009).

A Pigouvian tax, is a type of tax levied on economic activities that generate negative externalities, such as pollution or traffic congestion. The purpose of a Pigouvian tax is to internalize the external costs associated with these activities, thereby aligning private costs with social costs, and encouraging more socially optimal levels of production and consumption. Road pricing serves as a Pigouvian tax to address travel demand. Pigouvian tax mainly addresses issues of congestion rather than emissions, noise, road damage, safety, etc.

The overarching objective of this study is to contribute to the array of approaches available to fortify the sustainability and societal acceptance of land transport ecosystems.

1.1 Aim of Paper

The central objective of this paper is to introduce a novel approach that has the potential to enhance the generation of revenue for local governments. This revenue would be earmarked for financing land transport infrastructure, its operational aspects, and effective management. Simultaneously, this approach is designed to mitigate the adverse environmental and public health consequences associated with land transport activities.

1.1.1 Problem Statement

The financing of land transport infrastructure and its operational aspects currently relies on public funds allocated through the government's budgetary resources. This funding allocation faces competition from other critical government initiatives and programs. Given the propensity of the South African economy to perform below expectations, resulting in insufficient financial resources for all government programs, including those related to land transport, detrimental consequences become evident in the form of inadequate transport infrastructure leading to an increase in road accidents (Statistics South Africa, 2024).

1.1.2 Scope of Paper

The purpose of this paper is to connect and emphasize the key factors involved in setting up either a Low Emission Zone or a Congestion Charge Zone. The main goals are to encourage sustainable transportation methods and to generate revenue specifically designated for local government purposes.

The paper's scope is intentionally constrained to the practical implementation and associated benefits of the proposed revenue collection approach. It is essential to acknowledge that certain critical facets remain outside the purview of this study. One

dimension not addressed in this paper pertains to the broader economic ramifications of the proposed revenue collection method. Another aspect that received limited attention is the financial implications linked to the technologies necessary for revenue collection, considering the substantial cost varying dependent upon the complexities of each scheme. Furthermore, the capacity of both local government entities and the Road Traffic Management Corporation (RTMC) to embrace and sustain this revenue collection program is a pertinent consideration left unaddressed in this study.

2. METHODOLOGY

The research methodologies employed in this study were systematic literature review and thematic literature review which are widely recognized approaches for gathering and synthesizing existing knowledge on a specific topic. The systemic literature review involves a systemic approach of identifying, gathering, and reporting qualitative information from various sources in a replicable manner. Meanwhile, the thematic literature review is an approach of identifying, gathering, and reporting qualitative information based on the pre-determined themes (Booth, 2012). To initiate the systematic literature review, the chosen keywords were: “low emission zone tax,” from the google scholar search engine which resulted in journals, conference papers and articles from different search databases totalling 155 000. For the thematic literature review, the chosen keywords were: "low emission zones," "Automatic Number Plate Technology (ANPR)," and "road financing emission standards."

Table 1 below shows the various journals, conference papers and articles that were downloaded from various databases:

Table 1: Databases and download files

Database	Files downloaded
Association for Computing Machinery Digital Library	1
Sage Journals	1
Institute for Fiscal Studies	2
International Journal of Sustainable Transportation	4
Wiley Online Library	1
ScienceDirect	1
Hacienda Pública Española / Review of Public Economics	1
World Resources Institute	1
University of Pretoria repository	2
University of Stellenbosch	1
The International Council on Clean Transportation	2
World bank	1
Governmental websites	3
Total	21

Inclusion Criteria:

- Include any of the keywords.
- Published.
- Full text access.
- English.
- Peer reviewed academical journals, articles, conferences papers.

Exclusion Criteria:

- Books (books are generally not freely available and may not provide the latest developments).
- Non-English.

The literature review process commenced with an exploration of international best practices, particularly examining existing Low Emission Zones (LEZs) in other parts of the world. By scrutinizing these established initiatives, the study sought to glean insights into effective strategies, policies, and technologies employed in mitigating vehicular emissions and enhancing urban air quality. Concurrently, the review delved into the legislative landscape of South Africa, aiming to provide a contextual understanding of the regulatory framework governing environmental conservation efforts within the country. This section offered valuable insights into the legal mechanisms and governmental directives shaping the adoption and implementation of LEZs in the South African context, thereby establishing a foundation for further analysis. Following the examination of national legislative contexts, the literature review proceeded to reveal the of emission standards in South Africa. Moreover, the review touched on the nature of automatic charging methods.

Subsequently, the literature review delved into the vehicle identification and detection technological aspects of LEZs, offering an overview of the available technology and its applicability in the South African context. The review explored strategies for enhancing public acceptance of revenue collection mechanisms associated with LEZs, recognizing the importance of stakeholder engagement and community involvement in fostering support for sustainable urban transportation initiatives. Overall, this review process laid the groundwork for a focused examination of LEZ technology and its potential implications for environmental conservation and urban sustainability in South Africa.

2.1 International Best Practice

The European guidelines such as the 2008/50/EC, the Singaporean Environmental Protection and Management (Ambient Air Quality) Regulations, and the Japan's Air Pollution Control Act (Act No. 97 of 1968) (2006 ed) restrict certain environmental pollutants through various administrations such as the LEZ adopted by cities such as London, Singapore, Tokyo respectively. This section highlights the benchmarking of LEZ between three international cities that have successfully implemented the LEZ and CC policies.

2.1.1 London

The city of London has successfully implemented the LEZ and the Congestion Charge (CC) policy of which the national government has legalized, and the local government has taken responsibility (Wang et al., 2017). The European Union supports a low emission zone information service that catalogues all active LEZs in the EU, specifying vehicle standards and compliance options for drivers, which include purchasing new vehicles, retrofitting old ones with emission-reducing technology, or refraining from driving within these zones. Nash et al., 2015 mentioned that (LEZs) were becoming increasingly popular among municipalities as a means to combat vehicular emissions that negatively impact human health. Initially, the LEZ was aimed at the freight sector in order for the replacement of most polluting heavy vehicles.

Poor air quality, largely stemming from vehicle exhaust emissions, contributed to around 300,000 annual deaths among European citizens (Nash & Whitelegg, 2015). London's

road freight produced about 240 million tons of particulate matter (PM_{10}), which is about 28% of London's total, 5 500 million tons (17%) of nitrogen and 250 million tons (4%) of carbon dioxide emissions (Broaddus et al., 2015)

All vehicles that entered the zone between 07:00 to 18:00 were charged a daily fee, which was £5 (Broaddus et al., 2015) at inception and in the later years became £11.50 (Wang et al., 2017), with an exception for vehicles that emitted 75g/km or less of CO_2 according to the Euro V standard for air quality. Incentives such as financial assistance to help London residents scrap, donate, or retrofit, cars, motorcycles and wheelchair accessible vehicles that do not meet the Ultra Low Emission Zone (ULEZ) emissions standards are in place with constructive management and continuous refinement (Transport for London, 2024).

Some of the challenges that were identified relating to the initiative were the negative impact on the low-income demographics, who to a greater extent incur increased costs (Gould et al., n.d). Further challenges highlighted by stakeholders were the reduction in businesses operating within the zones, cost implications on the logistics companies and division of charges between public transport operators and passengers. Some benefits of the initiatives were the improvement in public transport services, reroute, optimized traffic signal timing and designated parking for nearby residents.

The ANPR technology was selected for the LEZ initiative. Lastly, some notable changes of the LEZ policy were as follows: more than 95% vehicles entering the zone were within the emission limits and the particular matter (PM) dropped by 2.46-3.07% within the zone and 1% outside (Wang et al., 2017).

2.1.2 Singapore

Road pricing systems (RPS) in Singapore are implemented as subsidiary legislation under the Road Traffic Act (RTA), which grants broad powers to the Minister for Transport to determine rules to regulate traffic.

In 2020, Singapore boasted the world's most advanced urban Electronic Road Pricing (ERP) system, characterized by its complexity, comprehensiveness, and technological sophistication. The system relied on a network of overhead gantries strategically positioned along major arterial routes, expressways, and encircling the central business district. Equipped with in-vehicle transponder units, passing passenger vehicles were automatically subjected to road charges ranging from SGD 0.50 to over SDG 5.00, with adjustments made as frequently as every five minutes. These charges aimed to regulate traffic speeds within specified ranges: 20 km/h to 30 km/h in the central business district and 45 km/h to 65 km/h along expressways (Theseira, 2020).

The subsequent ERP system the Global Navigation Satellite System (GNSS)-based road pricing system, which was to be installed in 2021 (with the road infrastructure already in place), would serve as a direct replacement for the gantry-based system.

Singapore's successful implementation of road pricing has often been attributed to robust government oversight and the cooperative attitude of its citizens towards governmental directives (Phang & Toh, 2004; Gu et al., 2018).

The GNSS ERP system consists of five networked components: An onboard unit (OBU) in each vehicle, a central computer system, a roadside unit antenna, and a mobile and roadside enforcement system. The key challenge in urban areas is reduced GNSS

accuracy (Ohno et al., 2007), which had to be specifically overcome through developing and building out roadside infrastructure. The OBU is a general-purpose navigation and computing device, it supports additional value-added services such as traffic information, parking payment, and activation and payment of off-peak or restricted-use vehicle licenses (LTA, 2015). Because GNSS has reduced accuracy in built-up areas, due to satellite signal reflection from tall buildings, or obstructions from terrain or infrastructure such as viaducts, Roadside Units (RSUs) must be deployed to augment the GNSS signal. The RSUs improve accuracy and serve as communications nodes for the system. The central computer system (CCS) co-ordinates information with the other subsystems. In particular, the CCS receives data from OBUs on charges levied and updates OBUs with new road charging schedules. the enforcement systems, consisting of fixed roadside monitoring and mobile vehicle-mounted monitoring, use DSRC signals to check passing vehicles for the presence of a working OBU with a valid payment account. Violators are identified using automatic number plate recognition systems. It should be noted that in Singapore, installation of the existing ERP in-vehicle units is mandatory for most registered vehicles, and this practice will continue for the new GNSS-enabled OBUs.

The road charge payment method – which requires a prepaid Cashcard to be inserted into the in-vehicle unit – was designed to avoid retention of motor vehicle identification data (which would be required under an account-based billing system).

The GNSS ERP system naturally raises more privacy risks than the existing ERP system, which can feasibly only track vehicles passing through specific fixed gantry points. The GNSS ERP system is presumably capable of tracking vehicles anywhere in Singapore or even abroad since the OBU continuously tracks vehicle location data. In response to questioning from Members of Parliament on motorist tracking under the GNSS ERP, the Singapore Government has committed in multiple Parliamentary debates to use the traffic location data from the GNSS ERP only in an aggregated format. In addition, ERP regulations have been adapted to allow account-based billing through credit/debit cards or bank facilities on an opt-in basis.

Singapore's GNSS ERP tender was awarded in February 2016 at a development price of R 7 605 412 800.00. The most important reason why Singapore policy makers invested in developing a GNSS ERP was the expectation that operating costs would be lower, and deployment flexibility would be greater, under GNSS. It was expected that GNSS would obviate the need to install fixed roadside gantry infrastructure – which took up land space and was unsightly – to facilitate road charging. Instead, the GNSS ERP system could be simply expanded via software to define new virtual charging zones or price schedules. In addition, policy makers had expressed concerns that the existing ERP infrastructure relied on proprietary technology, increasing maintenance and operating costs: a GNSS system, if it relied on open-source technology, would reduce such costs.

2.1.3 Stockholm

In the city of Stockholm, the LEZ and CC (in the inner city and surrounding districts) were successfully implemented in 1996 and 2007, respectively. Gantries were strategically positioned at entry points to the congestion charge zone, such as major roads and thoroughfares leading into central Stockholm. The charging was implemented between 6:00 am – 6:30 pm, Mondays to Fridays.

The rates charged about SEK 35 (R59.40) on passing gantries and SEK 105 (R178.21) daily maximum, of which the collected revenue is dedicated to infrastructure development in the city (tax bill has details of the revenue allocation). Various payment methods were

available to motorists, including prepayment, electronic toll collection systems, and payment at designated service points. Automatic number plate recognition (ANPR) technology was employed to monitor vehicle entries and facilitate fee collection.

Emerging challenges that were highlighted were vehicle licence plates theft, boycotts by the public, tampering with the vehicle licence plates, technical glitches with the charging system and the privacy of vehicle owners. Further challenges raised by stakeholders include negative impact on retail businesses within charging zones, business migration and pushback from the public.

Some benefits that were noted were the extension of public transport services and improved non-motorized transport infrastructure.

Public awareness was achieved through surveys, frequent policy implementation announcements and making use of conventional communication tools.

Some notable changes that resulted from the CC were include a decrease in vehicle emissions of 10% to 15% in the inner city and about 21% decrease in traffic volumes and a notable change with the Particulate Matter (PM) emissions from trucks decreased by 40% after four years of implementing LEZ (Wang et al., 2017).

2.2 Legislative Overview

South Africa is a signatory to both the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement of 2015. Consequently, South Africa bears a legal obligation to contribute to the global reduction of greenhouse gas emissions (GHG). Additionally, Section 156(1) of the Constitution affirms that municipalities possess executive authority in the realm of local government matters delineated in Part B of Schedule 4 and Part B of Schedule 5, which notably encompasses the domain of air quality.

In compliance with the National Environmental Management: Air Quality Act 39 of 2004 (NEMAQA), local municipalities are mandated to formulate an Air Quality Management Plan (AQMP) to ensure adherence to the national ambient air quality standards prescribed in the legislation. In fulfilment of Section 15(2) of NEMAQA and the stipulations within Chapter 5 of the Municipal Systems Act, municipalities are obliged to integrate an air quality management plan into their Integrated Development Plan (AQMP, 2019). Section 11(b) of the NEMAQA empowers municipalities to establish local standards for emissions from mobile sources in the municipality. This effectively means that local government standards may specify compliant and non-compliant motor vehicles. If national or provincial standards have been established for any particular substance or mixture of substances, local government may not alter any such national or provincial standards except by establishing stricter standards for the municipality or any part of the municipality.

The Minister or Member of the Executive Council (MEC) may allocate functions to a municipality in accordance with the National Land Transport Act (NLTA), provided such allocation is in accordance with the Constitution and the Municipal Systems Act. Notably, one of the functions of the Minister under the NLTA, as per Section 5(4)(v), is to encourage the efficient use of energy resources and to limit adverse environmental impacts related to land transport. Section 28(1), subject to the Municipal Fiscal Powers and Functions Act, 2007 (Act No. 12 of 2007), authorizes a municipality, having established a municipal land transport fund (MLTF) in accordance with Section 27 of the

NLTA, to impose user charges, which may vary depending on the circumstances, on specified classes of motor vehicles entering designated areas at specified times. The proceeds from these charges are allocated to the MLTF.

The development of an AQMP and its inclusion in the IDP is a mandatory prerequisite for all municipal authorities, as stipulated in Section 15(2) of the NEMAQA. A Low Emission Zone (LEZ) is an environmental management instrument with direct implications for traffic flow and must therefore be incorporated into the primary transport planning framework of the municipality.

The LEZ implementing agent of the local municipality is legally bound to fulfil a multitude of operational obligations such as: engaging in consultations with the Provincial Government and National Government regarding the implementation of an LEZ.

The adoption of CO2 emission standards for new vehicles, or an equivalent metric for fuel economy, would produce significant CO2 emission reductions and fuel savings, ranging from 11.6% for a short-term policy design to 28.4% for a long-term policy case; both cases evaluated to 2050. This evaluation considers that the South African fleet is expected to double in size by 2050. The economic benefits of adopting the standards were estimated between 26 and 64 billion rand, and proportional to the level of ambition of the standards (Posada, F. 2018).

2.3 Emission Standards

The current vehicle registry in South Africa is managed through the National Traffic Information System (NATIS), overseen by the Road Traffic Management Corporation (RTMC), an entity of the National Department of Transport (NDoT). According to the December 2023 registry, there were about 11 726 271 million self-propelled vehicles in South Africa. Approximately 17% of all passenger vehicles in South Africa are equipped with Diesel engines (ICCT, 2017). Additionally, the National Association of Automobile Manufacturers of South Africa (NAAMSA) website offers pertinent statistics that facilitate the calculation of petrol and diesel vehicle demographics. Leveraging existing vehicle data enables estimation of compliant and non-compliant vehicles, thereby providing a rough approximation of potential revenues through predetermined daily Low Emission Zone (LEZ) charges.

There exist international standards for vehicle emissions that were developed through the United Nations World Forum for the Harmonization of Vehicle Regulations, and these form the basis of vehicle emission standards adopted in Europe and many other countries. The standards used in Europe are called Euro Standards. The amount of Carbon Dioxide (CO_2) a vehicle will produce from the exhaust pipe is directly linked to the amount and type of fuel it uses (Ford, 2024). The European emission standards, often referred to as "Euro standards", are a set of regulations established by the European Union (EU) to limit the emissions of pollutants from vehicles, primarily aimed at reducing air pollution and improving air quality. These standards set specific limits on various pollutants, such as nitrogen oxides (NOx), particulate matter (PM), carbon monoxide (CO), and hydrocarbons (HC), that vehicles can emit.

The higher the Euro standard number, the stricter the emissions limits. The current Heavy-duty vehicles (HDV) emission standards in South Africa are Euro II, first introduced in Europe more than 20 years ago and phased out long ago there and in other major economies. Diesel engines that lack modern emission control devices produce $PM_{2.5}$, soot, nitrogen oxides (NOx) and other pollutants in large quantities (ICCT, 2022).

The average CO_2 emissions of new passenger cars in South Africa, tested under the New European Driving Cycle (NEDC), was 148 gCO_2/km in 2015. The equivalent metric in terms of fuel consumption is 6.3 L/100 km. A comparison of the South African (SA) passenger car fleet with that of Europe shows that the SA fleet emits, on average, 22% more CO_2 than the EU fleet, which is rated at 121 gCO_2/km (Posada, 2018).

Petrol vehicles are the main consumer choice among SA consumers, with 82.9% of the new vehicle market. Diesel is the second largest fuel option, with 16.9% of sales (Posada, 2018).

2.4 LEZ Charges

A similar LEZ charge system which is outlined in this section of the paper can be adopted in South Africa. The LEZ sets specific emission standards that vehicles must meet to avoid being charged. The standards are based on the European Emission Standards and are typically stricter for newer vehicles. Vehicles that meet these standards would not be charged.

Charging Bands: Vehicles that do not meet the LEZ standards would be subject to charges based on their size and emissions. The charges can be divided into bands, with larger and more polluting vehicles paying higher fees. The bands and daily charges could be as follows:

- Band A: The least polluting vehicles, such as Euro 6 diesel and Euro 4 petrol vehicles, are exempt from LEZ charges.
- Band B: Vehicles that do not meet the Euro 6 (diesel) or Euro 4 (petrol) standards but meet Euro 3 (diesel) or Euro 2 (petrol) standards are subject to a daily charge of about R 95.00.
- Band C: Vehicles that do not meet the Euro 3 (diesel) or Euro 2 (petrol) standards are subject to a daily charge of about R190.00.

The daily charges could be structured to enable private vehicle owners to maintain their vehicle usage while also incentivizing a transition towards new energy vehicles.

Penalties: If a vehicle does not meet the LEZ standards and enters the zone without payment, the owner can receive a penalty charge notice (PCN), which can be substantial.

2.5 Revenue Collection Technology

Over the years different technological innovations have been introduced all over the world to capture land transportation data. These technology innovations have also been introduced for the purpose of performing relevant revenue collection even for LEZs and CCZs. The Automatic Number Plate Recognition technology, which is what is suggested in this paper for the purpose of the LEZs and CC in South Africa is briefly discussed:

(a) Automatic Number Plate Recognition (ANPR)
Automatic Number Plate Recognition (ANPR) technology is a powerful tool used in the field of surveillance and law enforcement. ANPR technology primarily involves the use of cameras and specialized software to automatically capture and read license plate numbers from vehicles. These systems have the capability to process a large volume of data quickly and accurately. ANPR technology can be used in various applications, including traffic management, toll collection, parking management, and security.

One of the key capabilities of ANPR technology is its accuracy in reading license plates. Advanced algorithms and image processing techniques enable ANPR systems to recognize characters on license plates, even in challenging conditions such as low light, bad weather, or when the vehicle is moving at high speeds.

Another important capability of ANPR technology is its ability to automatically cross-reference the captured license plate numbers with a national number plate database system i.e., eNatis. This database contains information about registered vehicles, including owner details, vehicle type, registration status, and even alerts for stolen vehicles or vehicles associated with criminal activities.

ANPR technology can also be used for tracking and monitoring vehicle movements. When integrated with a national number plate database system, it can help track the movement of vehicles over time, allowing authorities to identify patterns, monitor traffic flow, and investigate specific vehicles of interest.

(b) The eNatis System

eNatis was launched in 2003 to replace the outdated National Traffic Information System (Natis). The primary goal was to create a more efficient and integrated system to manage vehicle and driver data and streamline various processes related to road safety and law enforcement. eNatis is responsible for managing a wide range of data related to vehicles, drivers, and road traffic incidents in South Africa. Its scope includes vehicle registrations and licensing, Driver licensing and endorsements, Vehicle ownership and history, Roadworthiness testing and certification, Accident reporting and analysis, Traffic fines and penalties.

Online Services: eNatis offers online services for both individuals and businesses, allowing them to apply for licenses, renew registrations, and perform other related tasks. It assists law enforcement agencies by providing real-time access to vehicle and driver information, helping in tracking down wanted individuals, and identifying stolen vehicles. The eNaTIS plays a critical role in road safety by ensuring that vehicles are roadworthy, and drivers have the necessary qualifications and endorsements.

2.6 Challenges With LEZ and CCZ

There was a concern pertaining to the risk of citizens driving through the LEZs losing their privacy and a large percentage error in detecting fraudulent drivers. The privacy was threatened by the high fraud detection (Jardí-Cedó et al., 2016) (Adam & Stroud, 2019) (Jardí-Cedó et al., 2016). An Electronic Road Pricing (ERP) system was a system designed to mitigate this problem by detecting fraud and preserving driver's privacy for cities with multifare LEZs. This system was more versatile with the calculation of the fees, based on distance driven, route or time and could be dynamically adjusted according to transit density in urban areas. However, dense areas were avoided by drivers due to the increased price, causing problems in other areas (Jardí-Cedó et al., 2016) (Adam & Stroud, 2019) (Jardí-Cedó et al., 2016). Furthermore, freight timing could not be affected by the pricing due to delivery and pick up times being dependant on the customers and not the freight operators, which resulted in a push-back by operators due to not being in control of the mode, route, and time of day for the deliveries. The Vehicle Kilometres Travelled (VKT) was unfortunately unresolved by implementation of LEZ and CCZ due to the large distances between logistic centres and their delivery sites (Broaddus et al., 2015). The implementation of road pricing was not accepted by the public due to issues

with paying for something that was formerly free, implications of double taxation and in equitability (Lindsey, 2009). High-end road pricing systems can be GPS-based, able to locate each vehicle by time and location. When this type of system was used to charge heavy goods vehicles in Germany, there were concerns regarding cost and accuracy of the vehicle location, especially in urban areas. Other concerns regarding road pricing were the financial implications that will affect poorer citizens (Nash & Whitelegg, 2014; Agago et al., 2020). The issue with charging emission tax was that it affected households that could not afford to live in the inner city and had to rely on their own cars due to inaccessibility to public transport, furthermore, households with children needed larger vehicles which resulted in higher emission tax. Electric vehicles on the other hand were not entirely exempt from emissions due to the emissions of Green House Gases based on the type of electric generation, furthermore, even with incentivising the use of electric vehicles, low-income households would not afford to attain such incentives (Vidyattama et al., 2021).

2.7 Improving Public Acceptance of Revenue Collection

In order to influence the public's vehicle purchase, replacement and scrappage decisions, the Vehicle Excise Duty (VED) could be combined with a scrappage subsidy that is based on the emissions. Reduction of emissions from motoring were achieved by fuel duties which discouraged people from driving their own private cars, furthermore, discouraging people from buying high-emissions cars. Incentives such as subsidies for buying new clean cars and scrapping old ones should be in place to encourage the public (Adam & Stroud, 2019). Another strategy for mitigating opposition from the public regarding road pricing would be by decreasing fuel tax. Cities in the UK implemented subsidies for citizens purchasing new electric vehicles (Nash & Whitelegg, 2014). Different vehicle types owned by households could be taxed differently as a way to incentivise the shift to more energy efficient and low-carbon vehicles. The amounts to charge could be determined by vehicle cylinders, vehicle tare weight or flat rate (Vidyattama et al., 2021).

2.8 Uses of Collected Revenue

Investing in infrastructure such as charging points for alternative fuelling, could potentially encourage people even more (Adam & Stroud, 2019). The collected revenue can be used within the same areas where it was collected to improve infrastructure such as non-motorized transport facilities and public transport. Furthermore, collected revenue can be utilized for land-use planning and accessibility planning by developing residential areas close to the desired destinations, which will shorten the travel distance and reduce car usage (Nash & Whitelegg, 2014).

3. RESULTS AND DISCUSSION

The literature review identified at least six major components or factors for operating a Low Emission Zone (LEZ) system and generating revenue, which are as follows:

- Public and political acceptance.
- The legislative framework, regulations, policy, rules, terms & conditions.
- Logical vehicle emission standards and LEZ charges.
- **Highly efficient technology** (focus of this paper).
- Availability of alternative means of transportation (public transport).
- Reinvestment of LEZ revenue (focus of this paper).

The central objective of this paper is to introduce a novel approach that has the potential to enhance revenue generation for local governments. This novel approach, the use of efficient and reliable technology, must be considered simultaneously with the other major components stated herein.

3.1 System Overview

To provide a clear visual representation of the essential infrastructure elements needed for the successful operation of LEZs Figure 1 offers an overview of the core components and key aspects that must be in place within the LEZ infrastructure system.

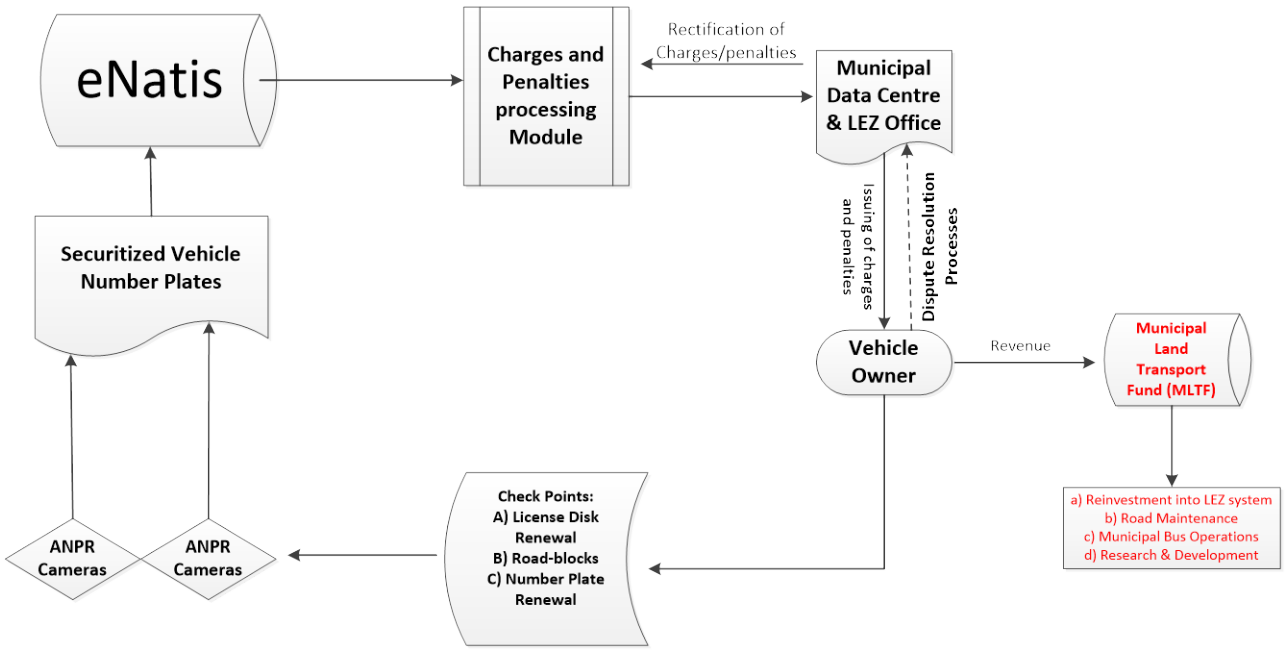

Figure 1: Revenue collection value chain

According to the findings of the literature review, establishing a database containing vehicle registration numbers (commonly known as number plates) is deemed essential for discerning compliant and non-compliant vehicles, and for associating them with their respective owners responsible for charges. The eNatis system and the ANPR technology stands as a proficient platform for executing this pivotal task, as demonstrated by its current utilization in speed cameras across South Africa; however, it will necessitate enhancements to effectively fulfil this particular objective. System enhancements may include an automatic charge calculation based on the classification and categorisation of a non-compliant vehicle, and communication to the owner. Furthermore, the same eNatis and ANPR technology can be used for other purposes such as the issuing of fines for speeding and safety and security, and thus making it a multi-purpose system.

It should be evident that the revenue collection value chain as depicted in Figure 1 that the value chain requires the involvement of RTMC which is a national entity, a provincial department responsible for transport regulation (as authorised by Road Traffic Act, 1996 (Act 93 of 1996 as amended) to facilitate number registration, which is a provincial entity, and any local municipality but preferably a metropolitan city where air emissions is scientifically proven to be a significant issue.

In essence, for the LEZ system to demonstrate effectiveness, the conventional means of ensuring compliance involve integrating the system with vehicle license disk renewal, number plate issuance or renewal, and traditional roadblocks.

While acknowledging that a portion of the generated revenue should be reinvested in operating the LEZ system, it is preferable for any surplus funds to be directed towards enhancing public transport infrastructure, systems, research, and the adoption of new energy vehicles.

4. CONCLUSION

It is evident that the LEZ and CCZs systems have been in place and operational in some developed countries. The major key factors to make the LEZ or CCZ system possible are to varying extents already functional in South Africa but will without a doubt require strengthening and clarification. The legislative framework is in place to facilitate the establishment of LEZs in South Africa.

The purpose of revenue collection is not to generate profit, but rather to tackle present issues related to carbon footprint and the funding of land transport infrastructure at the local municipality level. However, it is essential for the national government, specifically the RTMC, to take a leading role in this initiative.

Sustained engagement with stakeholders is highly important in such initiatives. Municipalities must clearly outline in advance how the collected revenue will be utilized to benefit land transportation and, ultimately, decrease the carbon footprint.

While Electronic Road Pricing (ERP) systems may appear severe to certain individuals, the profound effects of climate change on society, particularly on transport infrastructure, should serve as a compelling force for innovation within the transportation sector.

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