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Managing Traffic Congestion Pricing, the Associated Equity Issues, and Establishment of Sustainable Funding for Transportation Infrastructures

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***Abstract* — Road traffic congestion, partly resulting from inefficient land use plans and the inadequacy of existing transportation infrastructure to transport people from various origins to various destinations, using the same paths, at the same time (without delay) is an issue of concern to humanity". Inadequate funding for transportation limits the number of roads that can be built to increase the capacity of the transportation network. Road traffic congestion pricing has been identified as a way of reducing congestion, as it makes the cost of travel more apparent to users, but there is concern about equity issues for those who may not be able to afford the price tag. This study used the records of vehicle miles travelled in a country to illustrate the variations in revenue that could be achieved with varied fuel efficiency of vehicles. As an illustration, a comparison of revenue that could have been generated (all other things being equal) using a vehicle-kilometre travel (VKT) pricing system as compared to fuel tax for a 5-year period was also done. This review noted that the VKT 'road user fee' pricing system is a viable way to make the cost of travel apparent to motorists and form a basis for equity between those who use fossil fuel vehicles and those who use alternative energy. In addition to presenting a simplified procedure for establishing a sustainable transportation finance system, this study also presented a simplified method to estimate the appropriate fuel tax, as well as VKT road user fee to achieve a self-funded transportation system.**

***Index Terms* — *c*ongestion pricing techniques, Equity issues, fuel tax, Sustainable funding for transportation, VMT road usage fee**

I. INTRODUCTION

Road traffic congestion is a concern in various parts of the world, especially during rush hours. The huge cost of congestion has attracted concern about this topic. Considering factors such as time wastage and frustration, traffic congestion affects the quality of life. Congestion leads to an increase in CO2 emissions, it is also critical for emergency vehicles such as police cars and ambulances (Mehdi et al, 2022). Traffic congestion occurs when the supply of roadways is less than the demand for the road (INRIX, 2023). According to the 2016 Queen's speech, reducing congestion which was estimated to cost the United Kingdom £ 20 billion was identified as one of the expected benefits of the modern transport bill. Identification, evaluation, and management of traffic congestion are important in the construction of smart cities (Chen et al, 2022). Traffic congestion is a vital factor that causes hindrance to travel (Jian et al, 2022). In urban areas where the number of vehicles on the road continues to outpace road infrastructure development, traffic congestion is a great concern (Ouallane et al, 2022). On expressways, traffic control is a complicated multivariable problem (Toan et al, 2022). The complexity of urban congestion requires that policymakers adopt different congestion control measures that are suitable for city-specific characteristics at the right time (Ayrat and Lin, 2022). The 2015 urban traffic scorecard report that was jointly published by Texas A&M transportation institute and INRIX, in 2014, indicated that Americans purchased extra 3.1 billion gallons of fuel, and travelled an additional 6.9 billion hours, resulting in congestion cost of $160 billion. The 2019 global traffic scorecard by INRIX found that due to congestion, Americans lost 99 hours a year (on average), costing Americans nearly $88 billion (INRIX, 2023). In China's major urban areas, traffic congestion is one of the most pressing challenges (Yang et al, 2020). Building transport infrastructure (traditionally new and better roads) to alleviate congestion remains a political priority that has serious consequences for the shaping of Australian cities (Low and Odgers, 2012). In addition to the environmental costs, another report also noted that congestion reduces the quality of life (Urban Transportation Task Force, 2012). A 2009 study by Transport Canada that was meant to measure at least some of the social and direct costs of congestion in the largest urban centres in Canada

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broke down the cost of congestion to 3 categories viz costs due to wasted fuel, costs due to lost time for drivers, and costs of emission of greenhouse gases over what the cost would have been in a free flow condition. The cost of congestion comes in many forms like lost time and wasted gas, higher cost of production, and lower productivity. These impact the economy. Increased pollution and greenhouse gas affects everyone. The nationwide congestion cost ranges from $3.1 billion under the 50% threshold, to $4.6 billion under the 70% threshold (Urban transportation task force, 2012). Note that the given threshold was the percentage of free-flow speeds. A 50% threshold will consider movement at less than 50% of free flow speed as congestion. If a free flow speed is 100km/hr, traffic flow below 50 km/hr will be considered congested under the 50% threshold. Although some warnings exist to the Transport Canada study, mostly because it did not consider the transportation of goods, other studies have also confirmed the huge cost of congestion to Canada's economy as relating to both freight movers and commuters. A Metrolinx study that examined the cost of congestion based on the difference between actual speeds, and optimal speeds during morning and evening rush hours noted that the cost of congestion to the regional economy, and directly to consumers in Hamilton, and the greater Toronto area is $6 billion per year (Urban Transportation Task Force, 2012). The problem of congestion is not limited to one geographic location. Hubert et al, (2011) in a study about 'common traffic congestion feature based on traffic data measured in the USA, the UK, and Germany' also noted that for a good proportion of the day, traffic on freeways is often congested in many countries of the world.

Congestion pricing is widely used for the reduction of urban traffic congestion (Chen et al, 2020). Among various travel demand management measures, Congestion pricing is very efficient (Soleimani et al, 2023). Lots of studies and papers recognized road pricing to be an economically sound and effective traffic management tool (Olszewski and Xie, 2005). Among other things, Gonzalez-Aliste et al. (2023) noted that the sustainable transportation effects of reducing urban traffic congestion through pricing include reduced pollution and increased quality of life. Anupriya et al. (2023) noted that under certain conditions, road capacity expansion may induce growth in traffic volume. The study also reported that results from their study suggest that the average speed in a network does not increase substantially with an increase in capacity. The knowledge of induced traffic amplifies the need for a multi-dimensional approach to the management of road traffic congestion (i.e., not focusing on the expansion of road capacity alone. This does not mean that road expansion should not be explored when needed). Pricing in combination with other measures (such as the creation of multimodal systems that allow motorists to consider other means of transport like bus, metro, bicycling, or walking) has been applied in congested capitals (Gonzalez-Aliste et al. 2023). In a study for Beijing, Yang et al, (2020) reported that road pricing will result in an increase in traffic speed within the city centre while yielding welfare and revenue gains. Xi et al, (2022) noted that there is an urgent need for effective policies and measures such as road pricing to help address the issue of congestion and vehicular emissions. The expected decline in revenue from fuel taxes (as the number of vehicles that do not use fossil fuel increases in the traffic stream i.e., reduction in potential revenue for infrastructure construction and maintenance) calls for further studies on the evaluation of the feasibility of alternative road pricing scheme to ensure sustainable funding for transportation infrastructure. In terms of equity issues, it is important that the poor are not priced out of the road. Hence, the goal of this project is to evaluate the potential for generating sustainable funding for transportation infrastructure while addressing the associated congestion and equity issues. The objectives of the study are presented below:

Study objectives

- Explore and discuss different ways to manage road traffic congestion through alternative transportation systems.
- Present a simplified methodology for the estimation of vehicle-mile travel VMT (or vehicle-kilometre travel VKT) road user fees for vehicles that do not use energy that is subjected to fuel tax (explore the feasibility of generating alternative funding for construction and maintenance of transportation infrastructure).
- Describe a simplified method for estimation of road-user fees for a self-funded transportation system.
- Discuss equity issues that are associated with the management of road traffic congestion.

A. Congestion and urbanization

There is a direct relationship between traffic congestion and residential density (James et al, 2022). The 2012 report by the Urban Transportation Task Force noted that the 3 largest urban regions of Canada accounted for 80% of the total urban congestion cost. Schrank et al, (2015) on a comparison of congestion in small, medium, large, and very large cities (for years 1982, 2000, 2010, & 2014) showed that congestion is higher with the size of the city. However, congestion is not only a big city problem. A United Nations report (2014) indicated that the world's population that is living in the urban area has increased from 746 million in 1950 to 3.9 billion in 2014 and that growth is forecasted to increase to 66% in 2050. Liu et al, (2010), in a study about 'A framework for evaluating the dynamic impacts of a congestion pricing policy for a transportation socioeconomic system', noted that in many parts of the world, population growth and urbanization have increased congestion. Given the huge land mass and the number of people in the world at large, the present population density of the world is very low. The problem of congestion certainly is not a problem of overpopulation in the world at large; it is also not only associated with the number of people that lives in a community alone, but it can be associated with the concentration of people at a certain geographic location (population density), in relation to the amount of available infrastructure, and the demand for that infrastructure. Noting that congestion increases with population density in any community, there is certainly a great need for efficient distribution of resources in every community globally, to ensure an even spread of people, and to avoid congestion in a certain region. Having policies that provide incentives for citing industries in villages and ensuring that rural areas have attractive infrastructures that can be found in big cities may help ensure a better distribution of people between urban and rural areas of various communities.

The fear of sprawling makes the discussion about the construction of new roads contentious. However, it cannot be disputed that population density in any location will increase with population growth. To avoid congestion and overcrowding, there is a need for the expansion of cities and communities. It is better when this is planned and coordinated than random to ensure that community resources are not overstretched. There are 2 approaches to transportation planning (Proactive and reactive approach).

- In a proactive approach, it is recognized that communities will grow and there is a need to continuously plan for the transportation network that would efficiently accommodate the growth including the width of roads (arterials, collectors, highways and freeways) to ensure an orderly development. (i.e., a proactive approach to transportation planning will ensure the development of a transportation master plan for community development in each municipality that ensures that people can access basic amenities and workplaces within reasonable distances from their homes). The transportation master plan can be a guide for transportation development for community expansion when the need arises.
- In a reactive approach to transportation planning, it is recognized that communities will grow but there is a lack of a plan for adequate guidelines for transportation networks in the community. i.e., the community does not have a plan of where new roads (arterials, expressways, freeways, LRT paths, etc.) are expected to be. Sometimes the transportation network development is left to the discretion of local building developers.

The proactive approach to transportation planning is a better approach. i.e., the development of a transportation master plan with a forecast of future growth in every community. In places where the responsibility for road maintenance is shared between various levels of government, a reasonable level of collaboration between these levels of government (e.g., local municipalities and provincial government) in the development of a transportation master plan for future community expansion and an agreement on the conditions for the transfer of the new road development for various government entities will be ideal. This will help ensure a well-planned community growth that caters to the accommodation needs of the society at large. It is possible that development may not completely follow the transportation master plan, especially if property prices are not controlled along the path of the planned roads. In light of this, it is good to have a dynamic plan that can be adjusted to ensure that the standards for road development and community development plans in every city are maintained. Efforts to follow the transportation master plan will involve government regulation to ensure adequate control of land prices along the path of the transportation master plans for every community. Multiple factors could contribute to road traffic congestion. Even if a city is designed with the concept of a 15-minute city (where various amenities and workplaces are planned to be within the reach of residents of different communities within a short period), some people could still live far away from their work either due to personal preference of where they want to leave or due to uncontrollable factors about where they find a good job. Hence, the issue of management of traffic congestion is dynamic. It will benefit from continuous research to identify opportunities for continuous improvement.

B. Traffic congestion and automobile production

There is concern about traffic congestion in various places around the globe, but global production of automobiles is on the rise. Figure 1 illustrates World's vehicle production statistics from 2004 - 2021. With the COVID-19 pandemic at high levels in 2020, the reduction in the production of both cars and commercial vehicles in 2020 is not unexpected. It will take a while to achieve stability in the supply chain disruptions. If for economic reasons, there is no interest in reducing the global production of automobiles, then in the effort to minimize congestion, the world has to find innovative means of managing the indirect cost of production of new vehicles, to reduce the cost of congestion in various places around the globe. This may include an increasing effort to create alternative modes of transportation that provide a high degree of safety for everyone, as well as a reasonable degree of comfort, and convenience, at an affordable cost. Hence, the topic of road traffic congestion reduction strategies, the associated equity issues, and efforts to generate sustainable funding mechanisms to support transportation infrastructure are important for the global transportation sector.

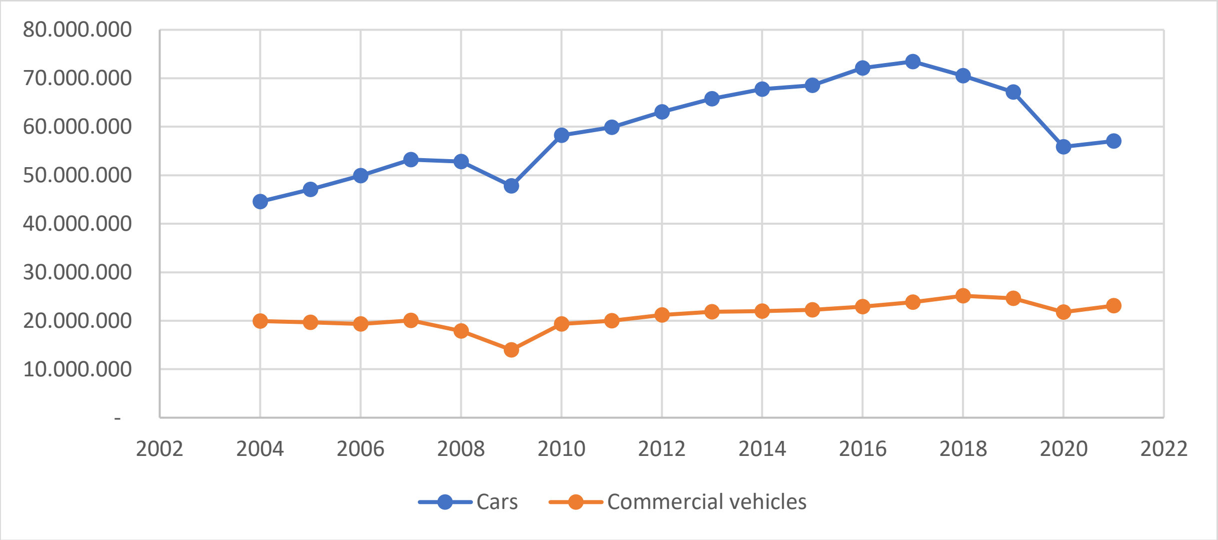

Figure 1. World vehicle production statistics (2004 – 2021). *Adapted from International Organization of Motor Vehicle Manufacturers

C. Traffic congestion and traffic safety

On the issue of congestion and traffic safety, Marchesini and Weijermars (2010) reported that the results from the literature is not consistent on this. While some studies noted that high volume-to-capacity ratios result in higher crash rates, one study does not find a relationship between congestion and crash frequency, while another study finds that crash rate decreases at high-density levels. Albalate and Fageda (2021) reported that better safety outcomes are achieved from effective measures to contain intense congestion. The result of a study by wang et al, (2013) suggests that increased congestion is associated with an increase in the number of accidents that results in serious injury and fatalities. Hence, it is important that the issue of

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congestion be given a higher priority. Further study on the impact of road traffic congestion and traffic safety in different communities is recommended.

II. ROAD TRAFFIC CONGESTION REDUCTION STRATEGIES, EQUITY ISSUES, AND GENERATING SUSTAINABLE FUNDING FOR TRANSPORTATION WORKS

A. Time of day pricing (tolls)

Even though traffic congestion imposes a huge cost on society, Safirova et al (2004) noted that budget limitations, environmental constraints, and neighbourhood opposition are not making it easy for new roads to be built. Policy analysts and transportation planners are looking for innovative ways of optimizing available road capacity with increasing demand for driving. Time-of-day pricing like congestion tolls has been used. However, in various situations, congestion tolls have seen serious opposition both from the public and from elected officials (Safirova, et al 2004). The congestion pricing concept is associated with the cost of delay for users, and the cost of constructing and maintaining the facility. This is similar to the concept used in utility pricing in which the pricing at peak periods is higher than in other periods. If the use of the commodity at peak periods can be greatly reduced, there may be no need to construct additional facilities that will not see frequent use in fewer peak periods (Fielding, 1995). Knowing that financing for public infrastructure is an issue that is facing the transportation industry, it is high time to have second thoughts about the use of congestion pricing and finding means to increase ridership of other modes of transport to reduce congestion issues. Delays at toll plazas are one of the reasons why tolls are unpopular, but electronic toll equipment allows the tolls to be collected without the vehicle coming to a stop (Fielding, 1995). Eliasson (2009) in a study about 'cost-benefit analysis of the Stockholm congestion charging system' noted that Stockholm's congestion charging system in which charges were imposed between 6:30 – 18:30 on weekdays on certain vehicles yielded a significant social surplus that is enough to cover the investment and operating cost.

Road pricing has been classified as regressive with respect to income as those who are poor disproportionately pay a larger percentage of their income when compared to the rich. However, the argument that has been given to support congestion toll is that when compared with other regressive pricing schemes like transportation sales tax, congestion toll is fairer, as transportation sales tax disproportionately burdens the poor who do not drive or drive just a little (Lisa, & Brian, 2010). On the equity side, it is good to remember that some people are not very wealthy, not because they are not hard working. The level of opportunity that an individual has may determine the amount of wealth the person will have. The issue of equity is one that every society should take seriously, as it does not seem fair for the poor to pay for subsidies for the rich. Transportation affordability is a pressing issue for the development of sustainable and equitable places (Molloy et al, 2023). Previous work by Bills (2024) reported that evaluations of public investments in transportation in the United States showed that the most vulnerable members of society are most likely to be affected by negative externalities of transportation infrastructure and policy changes. As the interest in sustainable practices in the transportation engineering sector rises, the pressure to adopt more equitable affordable and environmentally-friendly mobility is necessary. Various local, regional and national governments have set initiatives to examine the existing and potential disproportionate impacts of social equity in transportation to low-income and minority populations (Beiler and Mohammed, 2016).

A progressive tax rate in which people pay to use public facilities appears to be a good system that needs to be further researched for implementation. It also does not seem equitable for a disadvantaged individual to remain in a traffic hold-up because he/she cannot afford to pay for a less congested lane. Efforts to provide an equivalent alternative for those who cannot afford to pay for the congestion toll may be a good way forward in a situation like this. For example, if a roadway experience traffic congestion and a municipality is considering the use of congestion tolls for the traffic, to an extent, provision of light rail transit (LRT) that can go at an equivalent speed or even faster than the free flow speed on the road may be seen as a relatively fair alternative for anyone that cannot afford to pay the congestion toll. To reduce the congestion, the

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municipality may increase the efficiency of the alternative mode (like the LRT) and ensure that it will be affordable for the poor while increasing the price of the congestion toll. The city of Calgary uses a sliding scale system in which the purchase price for transit service is based on income. The lower the income, the lower the price an individual will pay for transit. Initiatives such as reduced prices of bus tickets for low-income earners in various communities (e.g., City of Edmonton, City of Calgary, etc), and reduced prices of bus tickets for low-income seniors and those on disability assistance (BC bus program) are good initiatives towards transportation equity. Transportation equity measures to ensure that some people are not priced out of the road would benefit from continuous improvement efforts in different municipalities.

B. Vehicle miles travelled pricing system versus fuel tax system

The fuel tax financing system has been a source of revenue for transportation programs. But special report 285 (2006) by the national academies of sciences, engineering, and medicine noted that recent events have increased the long-standing concerns that fuel taxes will become an unreliable source of revenue in the future. Among other things, special report 285 (the fuel tax and alternatives for transportation funding) includes recommendations that the government should adjust user fee rates to align the payments with cost demands, and create incentives for cost-conscious use of the road. It was also recommended that government explore the use of mileage charging and road-use metering system. With the increase in the number of electric vehicles on the roads, the revenue from fuel tax will be reduced. Adams et al (2001), in a report about ‘financing transportation in California: Strategies for change,’ noted that the quality of life of Californians depends on the freedom for people and goods to move from one place to the other in a safe, and timely manner at a reasonable cost, and having reasonable mode and route choice alternatives. The fact that moving from one place to the other is part of the way of life of humans makes the quality of transportation systems one of the important metrics to evaluate the level of development of a community. However, a good thing to note is the fact that the associated cost of this movement is also important. It is obvious that the cost of transportation should be reasonable for people to be able to use the facility at a reasonable level of comfort. To maintain a reasonable level of comfort, the transportation facilities need to get maintained. The costs associated with the construction of the infrastructures also bring the need to have reliable revenue to maintain the built infrastructure, replace the existing one, or construct additional infrastructures when the need arises.

In the days when fossil fuel is the major source of energy to power automobiles, relying on fuel tax as the ‘road usage fee’ may not be a bad idea. Nevertheless, increasing demand for limited road spaces necessitates a reasonable increase in the revenue to maintain, supply, and optimize transportation infrastructure to meet that demand without having the huge cost of congestion. The presence of automobiles with alternative energy sources has also necessitated the need to switch to a road user fee system where everyone that uses the road pays their fair share to maintain the infrastructure. Depending on the cost to run a vehicle with alternative energy in various communities, manufacturers of automobiles that use fossil fuel may soon be faced with more pressure to produce automobiles that can compete with the cost of running a similar vehicle that uses an alternative source of energy. Advanced technologies in automobile production, especially in the alternative energy system are moving the world closer to having a cheaper means of transportation in various municipalities. To have a better visualization of the impact that these innovative technologies may bring on the transportation finance system, and how soon people may shift to automobiles with an alternative form of energy, continuous study of the cost of energy to run automobiles with alternative energy (e.g., electricity), as compared with fossil fuel in various municipalities globally is recommended. Widespread distribution of this information will be helpful when consumers are planning the purchase of an automobile. It is also expected to drive competition between electric-powered car manufacturers and fossil-powered car manufacturers to see who will be able to produce a better and more cost-effective system for the end users.

The vehicle miles travelled (VMT) road-user-fee system has great potential to create a fair billing system for vehicles that rely on the use of fossil fuel, and those that do not use fossil fuel. However, considering the way automobiles are built, switching to an efficient vehicle mile travel system may require an automated billing system where users get billed for road usage fees. At this time, it is common that automobiles come with odometers that show the distance the vehicle has travelled, but in many places, it is not common to hear about a billing system that is based on the kilometres or the mileage that the vehicle has travelled. Implementing a system in which all new vehicles will come with an automatic mileage reporting system for appropriate billings for road usage, and maintenance fees may need a consensus agreement by policymakers in various municipalities globally. For home energy use, it may not be uncommon to hear about meter readers. However, for an efficient vehicle mile travel system, it will be good to see a vehicle to Infrastructure (V2I) communication, with an electronic update system that does not require manual recording and submission of the kilometres/miles that the vehicle has travelled within a specified period. More research on a system such as this, followed by appropriate policies such as "all newly manufactured automobiles be equipped with systems that are able to have V2I communications, and can automatically capture and record the mileage travel for appropriate billing systems" may be helpful. Vehicles that use fossil fuel may also see an adjustment in fuel tax to a level that meets up with the cost needed for road maintenance and construction of new transportation infrastructures. Mofolasayo (2018) in his research report on 'evaluation of potential policy issues when planning for autonomous vehicles' also recommended that efforts should be made to implement systems that can automatically capture, and report vehicle miles travelled by all vehicles, in all communities, for periodic billing in a road usage finance system, to ensure that autonomous vehicles that are powered by electricity can pay their share of the road maintenance fee.

The proposed vehicle-to-infrastructure electronic billing system may be further designed to automatically capture the vehicle miles travelled within various districts of a municipality at different times of the day, by capturing the odometer reading (and time) when the vehicle enters a certain district, and also recording the odometer reading, and the time the vehicle leaves that district. The proposed system may be very helpful if there is a desire to have separate billing rates for the use of automobiles in various areas of a municipality at various times of the day (i.e., varied mileage charge per hour of the day). This may be achievable if an adequate vehicle-to-infrastructure (V2I) communication system is available that can record the time of the day that each vehicle passes through a congestion-prone area, and automatically prepare the billing system in accordance with a specified time of day VMT use-charge. This charge may not be a good idea if there are no reliable alternate modes of transportation like LRT, efficient bus systems, etc. that can transport people to their destination at a reasonable time. To make sure that this does not make commuting unnecessarily difficult for people, there may be a need to establish situations in which the higher VMT charges will have an additional subsidy for certain people with limiting economic situations in congestion-prone areas. For example, it may not be a good idea to have a low-income family (residing in congestion prone area) that has to transport children to school at the morning peak hours pay an exorbitant price for commute during that period, if there are no alternatives and reliable means of transportation like school buses to take the children to school. Having reasonable additional subsidies for low-income families that reside in areas with higher VMT road usage fees (during congestion periods) may be a good thing to explore to ensure equity for the poor in that locality. There will be a need to ensure a great level of security in such systems to prevent breaches of privacy of people in various communities globally.

In addition to any potential challenge which may make it difficult to increase fuel tax to align with usage cost, there is an interest in both saving money at the pump for consumers and seeing progress towards the effort to achieve energy independence. In this light, the corporate average fuel economy (CAFE) that was enacted by congress in 1975 was aimed at reducing energy consumption and increasing the fuel economy (NHTSA). While improvements to the CAFE standards are hoped to save consumers money at the pump (for those who bought automobiles with good fuel efficiency), it may not increase the revenue from fuel tax (if consumers do not drive more because of increased fuel efficiency). However, other benefits may also come with improved fuel efficiency. A report by the National Highway Traffic Safety Administration (NHTSA) on Average Fuel Economy Standards for Light Trucks Model Years 2008 -2011 indicated that the unreformed CAFE standards for MY 2008, 2009, and 2010 are 22.5, 23.1, and 23.5 miles per gallon (mpg) respectively. The Final Environmental Impact Statement (FEIS) that was made to evaluate and show the potential environmental impacts of CAFE standards for non-passenger and passenger automobiles, and reasonable alternative standards showed that there is interest in knowing the cumulative impacts of reaching 35 mpg total fleet requirement for 'MY 2016 – 2020' (NHTSA). As of August 2015, the fuel consumption for the average new car is 25.4 mpg (NREL). That means 1 gallon will drive 25.4 miles, or 1 mile requires 1/25.4 gallons =0.0397 gallons (25.4 mpg = 0.0397 gallons per mile). The goal to be energy efficient is a great idea that should also remind everyone about the need to have a good evaluation of alternative means of generating revenue for transportation infrastructure, to ensure that revenue for transportation infrastructure is not hindered by the goal to be energy efficient.

In evaluating the impact of congestion, it is good to know that the higher the congestion, the higher the fuel consumption, the higher the revenue that is generated from the sale of fossil fuel, and the higher the profit for those that are involved in the business of fossil fuel. It is known that the source of energy for transportation systems is diverse. Whenever an issue deals with profit for some organizations, there is a need to handle such matters in a way that avoids bias towards any group of people, putting the interest of humanity at large at heart. The issue of congestion management should be handled in such a way that there will not be anything that indicates a bias toward profit, or revenue generation at the expense of the long-term benefit of society. Energy sources are categorized into both renewable, and non-renewable energy sources. In any case, it is not a good idea to waste resources. In addition, the lifespan of humans in this world is limited. We should all make a good effort to have adequate systems to make the best use of our time and aim at 'improving the quality of life.' This should include efforts to reduce time spent in traffic hold-ups.

An economic principle that has been long accepted suggests that to maximize the benefits an economy provides to its members; prices have to be set at the same level as the marginal cost. In terms of public infrastructures such as transportation networks, this theory will favour the concept of self-financed transportation systems. Economic and population growth comes with an increase in the demand for road space. Hence, at some point, there will be a need for further expansion (Verhoef and Mohring, 2009). It is important that efforts be made to create strategies that allow for self-sustainable roads. That means adequate revenue needs to be generated from the use of the roads to allow for the maintenance of good and safe roads, and to expand various sections of the roads in accordance with the demands from the increase in population, as well as construct and maintain alternative modes of transportation. If sustainable revenue will be generated from the use of the roads, it is important that people in the community have sustainable salaries. If many people in various communities around the globe do not have sustainable wages, there will be a need for government subsidies for the use of the road for large portions of the population. Since 1962, Mohring and Hartwiz derived conditions in which optimally designed and priced roads would be self-financing (Vehoef and Mohring, 2009). This study shows a simplified method to develop a self-sustainable transportation finance system.

III. METHODOLOGY

To evaluate the potential benefits of the vehicle-mile travel system as a means of generating revenue for transportation infrastructure the vehicle-miles travel (VMT) on highways from the US department of transportation's website (US DOT), bureau of transportation statistics, was used to analyse the two systems (i.e., VMT billing system & fuel tax system). Previous work has shown variations in the fuel economy of vehicles between 11.9mpg (lowest value in 1973) and 25.4 mpg (as of August 2015, NREL). There is also interest in reaching 35mpg. U.S energy information administration reported that as of January 1, 2023, the taxes and other fees on gasoline and diesel fuel (cents per gallon) are: 18.40¢/gallon and 24.40 ¢ /gallon for gasoline and diesel fuel respectively (for federal), 31.63 ¢ /gallon for gasoline and 33.88 ¢ /gallon for diesel (average of total state taxes). Using 32.76 cents for fuel tax (for illustrative purposes only), the expected revenue for varied average fuel economy (11.9mpg, 17 mpg, 22mpg, 27mpg, and 35mpg i.e., 5.1, 7.2, 9.4, 11.5, and 14.9 kilometres/Liter) was evaluated for a 5-year window (2015–2019). The Federal Reserve Bank of St. Louis (FRED) published the national totals of state tax revenue for motor fuel sales tax by the U.S. Census Bureau. The published revenue that was generated for the fourth quarter of the year 2019 was used to estimate how much the equivalent VMT road user fee will be. This equivalent road user fee was obtained by dividing the revenue generated (by states and local governments in motor vehicle fuel taxes in 2019) by the total distance travelled for the year. This yields 1.64 cents per mile for the year 2019. Note that this is with the assumption that the revenue generated by the federal government from motor vehicle fuel tax is included in the records for state and local governments. When the estimated infrastructure spending for 2019 was used as the targeted amount for the revenue from transportation, the VMT road-user-fee increased. This is explained later in the manuscript. Figure 2 illustrates a simplified procedure for establishing a sustainable transportation finance system (Using VMT road user-fee and fuel tax system).

The state of Oregon in the road usage charge pilot program (2013) noted that 1.56 cents per mile were charged for the pilot program, which was equivalent to 30 cents of fuel tax per gallon (Oregon.gov). In Bill 810 by the senate of the state of Oregon, 5000 initial volunteer motorists were to be charged 1.5 cents per mile. The analysis in this report assumes that all vehicles that contribute to the vehicle miles travelled as seen in the information from the bureau of transportation statistics website all have the same fuel efficiency. In real life, it is known that the fuel economy of various vehicles differs. However, this analysis shows the feasibility of the vehicle mile travel system on a nationwide scale. Statista (2023) reported the percentage of GDP that some selected countries spend on infrastructure spending. To estimate the cost to achieve a self-funded transportation system, the cost of infrastructure spending was used as a target value to estimate what the vehicle mile travel (VMT) road user fee would have to be to achieve the targeted amount for infrastructure spending. A similar estimation was also done to see how much the motor vehicle fuel tax needs to be to achieve a self-funded transportation system.

A. Revenue from fuel tax

$$Revenue\ (\$)\ = Total\ mileage\ traveled\ (miles)\ x\ Fuel\ tax\ \left(\frac{\$}{gallon}\right)\ x\ Rate\ of\ fuel\ use\ \left(\frac{Gallons}{miles}\right) \quad (1)$$

This can also be expressed as:

$$Revenue\ (\$)\ = Total\ distance\ traveled\ (kilometers)\ x\ Fuel\ tax\ \left(\frac{\$}{Liter}\right)\ x\ Rate\ of\ fuel\ use\ \left(\frac{Liters}{Kilometers}\right)$$

Note: 1 mile = 1.60934km, 1 US gallon = 3.7854 liters (https://www.metric-conversions.org/)

i.e., The revenue from fuel tax

$$Revenue\ (\$) = Amount\ of\ fuel\ used\ (Liters) x\ Fuel\ tax\ \left(\frac{\$}{Liter}\right) \quad (2)$$

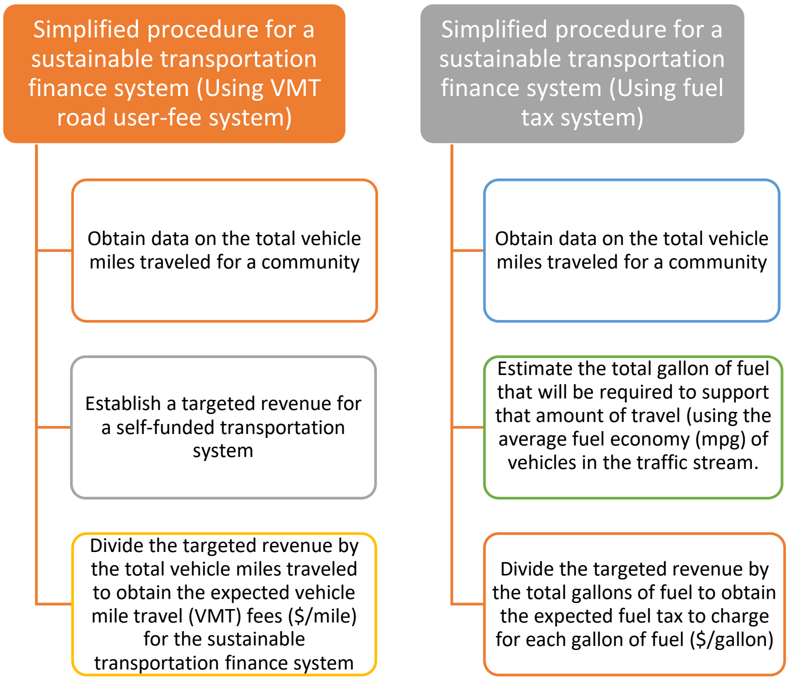

Figure 2. Simplified procedure for establishing a sustainable transportation finance system (Using VMT road user-fee and fuel tax system)

Note that if the VMT road user fee system is used, there will be a need for a study of road user behavior, especially as it relates to efforts to avoid the road user fees through reduction of the extent of driving. The second estimate on expected fuel tax per gallon for a self-sustainable transportation funding system is based on the assumption of the same type of fuel for all the vehicles in the traffic stream.

Estimation of quantity of fuel used

$$Quantity\ of\ fuel\ used\ (Gallons) = Total\ mileage\ traveled\ (miles) x\ Rate\ of\ fuel\ use\ \left(\frac{Gallons}{miles}\right) \quad (3)$$

$$i.e., Quantity\ of\ fuel\ used\ (Liters) = Total\ mileage\ traveled\ (km) x\ Rate\ of\ fuel\ use\ \left(\frac{Liters}{Kilometers,\ km}\right)$$

Alternatively, the estimated quantity of fuel used can also be done by dividing the total miles travelled by the average fuel economy (mpg). i.e.,

$$Quantity\ of\ fuel\ used\ (Gallons) = \frac{Distance\ traveled\ (miles)}{\left(fuel\ economy\ \left(\frac{miles}{gallon}\right)\right)} \quad (4)$$

$$i.e., Quantity\ of\ fuel\ used\ (Liters) = \frac{Distance\ traveled\ (Kilometers)}{\left(fuel\ economy\ \left(\frac{Kilometers}{Liter}\right)\right)}$$

B. The targeted revenue for a self-sustaining transportation system

Expected revenue from vehicle mile travel road user fees system

$$Expected\ revenue\ from\ vehicle\ mile\ travel\ (VMT), \$ = VMT\ fees\ per\ mile\ \left(\frac{\$}{mile}\right)\ x\ Total\ mile\ travel\ (miles) \quad (5)$$

$$i.e., Expected\ revenue\ from\ vehicle\ kilometer\ travel\ (VKT), \$ = VKT\ fees\ per\ kilometer\ \left(\frac{\$}{kilometer}\right)\ x\ Total\ distance\ travel\ (kilometers)$$

If the transportation system will be self-sustaining, the planned revenue from vehicle mile travel fees must be able to cover all the associated expenses. Note that by making the road user fees visible to consumers, as in the VMT fee system, depending on the price for the road use, there is a likelihood that there will be more consciousness about the use of roadways, as people who want to save more money may consider alternative means of transport if they are safe, clean, reliable, and efficient. To ensure that transportation systems can pay for their maintenance, it is important to ensure that adequate fees exist for road usage in terms of vehicle mile travel (VMT) fees. In this case, the targeted revenue to be generated from the transportation system should include the cost to purchase and maintain the infrastructure that is needed for the VMT fee system, worker salaries, the estimated cost for the maintenance of existing infrastructure, and the estimated cost to support the construction of new infrastructures. An extra allowance for contingencies may be included. This may include estimated amount to allow for travel avoidance when some people change their travel mode to avoid the road user fees (while the infrastructure still needs to be maintained), and allowance for various subsidies to finance equity initiatives.

C. The targeted revenue for a self-sustaining transportation system (using the VMT system)

$$The\ targeted\ revenue\ for\ a\ self\ sustaining\ transportation\ system\ using\ the\ VMT\ system = Operation\ cost\ (Worker\ salaries + Cost\ for\ purchase\ and\ maintenance\ of\ Infrastructure\ for\ the\ VMT\ fee\ system) + Estimated\ cost\ for\ the\ maintenance\ of\ existing\ infrastructure + Estimated\ cost\ to\ support\ the\ construction\ of\ new\ transportation\ infrastructure + Extra\ allowance\ for\ contingencies \quad (6)$$

The vehicle miles travel fees for a self-sustaining transportation system can be based on the targeted revenue and the anticipated amount of travel (i.e., expected travel miles). The expected travel miles can be a projection based on the travel miles from previous years.

$$Vehicle\ mile\ travel\ (VMT) fees\ \left(\frac{\$}{mile}\right) = \frac{Targeted\ revenue}{Anticipated\ travel\ miles}\left(\frac{\$}{mile}\right) \quad (7)$$

$$i.e., Vehicle\ kilometer\ travel\ (VKT) fees\ \left(\frac{\$}{kilometer}\right) = \frac{Targeted\ revenue}{Anticipated\ travel\ kilometers}\left(\frac{\$}{kilometer}\right)$$

D. The targeted revenue for a self-sustaining (self-funded) transportation system (using the fuel tax system)

$$\begin{aligned} &The\ targeted\ revenue\ for\ a\ self\ sustaining\ transportation\ system\ using\ the\ fuel\ tax\ system \\ &= Operation\ cost\ (Worker\ salaries \\ &+ Cost\ for\ purchase\ and\ maintenance\ of\ Infrastructure\ for\ the\ fuel\ tax\ fee\ system) \\ &+ Estimated\ cost\ for\ the\ maintenance\ of\ existing\ infrastructure \\ &+ Estimated\ cost\ to\ support\ the\ construction\ of\ new\ transportation\ infrastructure \\ &+ Extra\ allowance\ for\ contingencies \quad (8) \end{aligned}$$

$$\begin{aligned} &Fuel\ tax\ for\ a\ self\ funded\ transportation\ system \\ &= \frac{Targeted\ revenue\ for\ a\ self\ funded\ transportation\ system}{Expected\ quantity\ of\ fuel\ for\ the\ total\ travel\ disatnce} \quad (9) \end{aligned}$$

In a mixed system where a combination of both the fuel tax and the VMT fees are used, for the transportation system to be self-sustaining, the targeted revenue across the fees system must be able to attend to all the associated fees that are necessary for a smooth running of the transportation system. The proportion of vehicles that use different road user fees may be factored into the evaluation to determine what the expected target revenue will be for various streams of vehicles. After knowing the targeted revenue for a self-sustaining transportation system in the community, the targeted revenue for vehicles that are on the VMT road user fee system may be based on the proportion of vehicles that use the VMT fee system, while the proportion of the targeted revenue for those who remain on the fuel tax system may also be based on the proportion of vehicles that remain on the fuel tax system. If all the systems in the economy are self-sustaining, there is a likelihood for a reduction in the debt burden of a nation (when the finances of the nation are well managed). If a loan is already taken for a project, this may be included in the ongoing operational cost that is expected to be covered by the targeted revenue. It is recommended that government officials, consultants and future researchers consider all the above costs when planning for a self-funded transportation infrastructure system in every community globally.

E. Equivalent road user fees for vehicles in the traffic stream

It is important to ensure that there is equity in the road use fees for vehicles that are configured for the fuel tax system and vehicles that do not use the fuel tax. Hence, the equivalent road use fees for vehicles that do not use fossil fuel can be estimated from the revenue from vehicles that use fossil fuel in reference to the total mileage (distance) driven by these vehicles.

$$\begin{aligned} &Equivalent\ VMT\ road\ use\ charge\ \left(\frac{\$}{mile}\right) \\ &= \frac{Total\ revenue\ from\ fuel\ tax\ from\ fossil\ powered\ vehicles}{Total\ mile\ travel\ by\ fossil\ powered\ vehicles}\left(\frac{\$}{mile}\right) \quad (10) \end{aligned}$$

$$\begin{aligned} &i.e., Equivalent\ VKT\ road\ use\ charge\ \left(\frac{\$}{km}\right) \\ &= \frac{Total\ revenue\ from\ fuel\ tax\ from\ fossil\ powered\ vehicles}{Total\ distance\ travel\ by\ fossil\ powered\ vehicles}\left(\frac{\$}{km}\right) \end{aligned}$$

Given that the traffic stream now has both fossil powered vehicles and vehicles that do not use fossil power, the total miles travelled by fossil-powered vehicles in a community can be estimated by subtraction of the total miles travelled by vehicles that do not use fossil power from the total vehicle miles for the community.

i.e., With an assumption of a uniform amount of distance travel by both fossil-powered and non-fossil-powered vehicles,

$$\textit{The total distance traveled by fossil powered vehicles} = \textit{Total distance traveled by all vehicles in the community} - (\textit{Proportion of vehicles that do not use fossil f} * \textit{Total distance traveled by all vehicles in the community})$$

$$TMT_{fp} = TMT_{av} - (\%N_{fp} * TMT_{av}) \quad (11)$$

Where:

TMT_{fp} is the total distance travelled by fossil powered vehicles, TMT_{av} is the total distance travelled by all vehicles in the community, and $\%N_{fp}$ is the proportion/ percentage of vehicles in the traffic stream that do not use fossil power. As of 2019, just under 5.4 million hybrid electric cars have been sold in the United States (this is 1.6% of all 333million new light-duty vehicle sales between 1999 and 2019) while just over 1.4million plug-in electric cars have been sold in the United States (40% of this is plug-in hybrids and 60% of those sales are in all-electric cars) (USA facts, 2023). Between 2011 and 2019, plug-in electric cars account for just under 1% of all 146 million new light-duty vehicle sales (USA facts, 2023). As the proportion of vehicle-mile that do not use fuel tax increase, there will be a need to consider this in the calculation.

IV. RESULTS AND DISCUSSION

Figure 3 presents an illustration of the comparison of US transit and vehicle distance travel between 1960-2020.

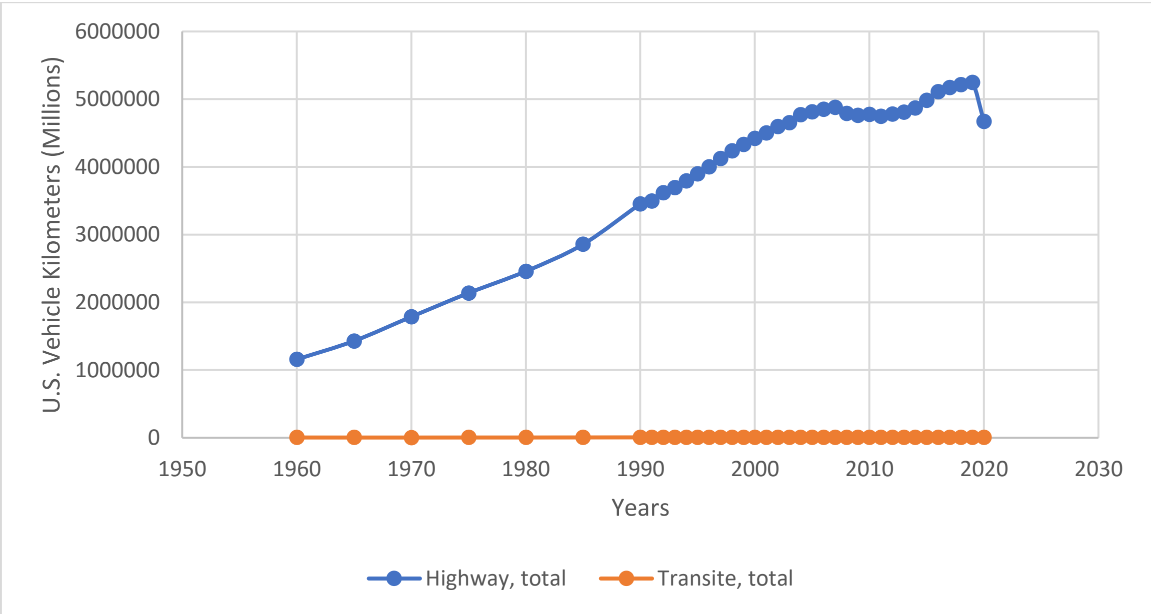

Figure 3 Comparison of US Highway Vehicle kilometers with Transit distance (kilometers) 1960 – 2020.
*Adapted from Table 1-35: U.S. Vehicle-Miles

Figure 3 showed that for the most part, the vehicle miles traveled increased from 1960 – 2020. The vehicle-kilometers traveled on transit do not show as much increase as seen for the total highway miles. More research on how to increase the comfort, convenience, cleanliness, and safety of the transit system, to increase ridership of public transit while reducing congestion on the roads is recommended.

A. Fuel consumption analysis for highway vehicles

Sivak and Tsimhoni, (2009) in a study about 'Fuel efficiency of vehicles on US roads: 1923–2006' used information about fuel consumed, and distances that were driven to calculate the fuel efficiency of different classes of vehicles, and overall fleet on the road. Sivak and Tsimhoni found that the fuel efficiency of the overall fleet decreased from 14 mpg (5.95 km/l) in 1923 to 11.9 mpg (5.06 km/l) in 1973. The efficiency was found to increase to 17.2 mpg (7.31 km/l) in 2006. A conversion rate 1 mpg = 0.425143707 km/l (https://www.mpgtolitres.com/mpg-to-kml) was used for this. Figure 4 showed that with increased fuel efficiency also comes a reduction in the amount of fuel consumed on the highway. The graph below shows an estimate of the amount of fuel for different fuel-economy.

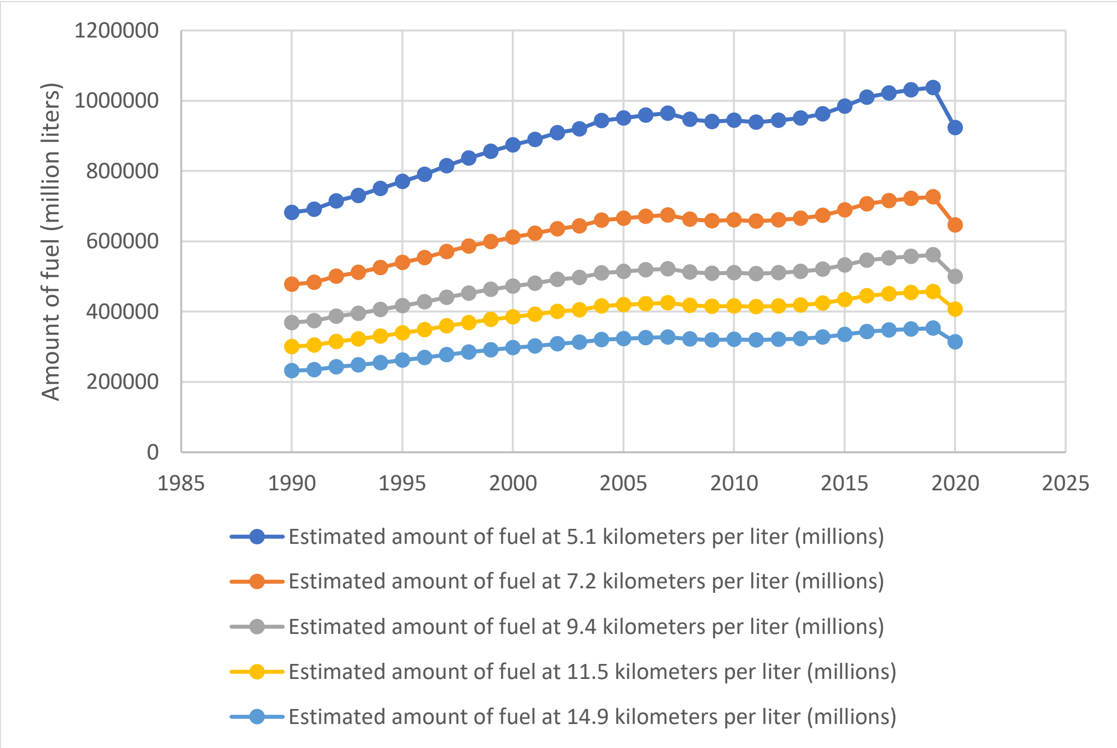

Figure 4 Effects of increased fuel efficiency on amount of fuel (million liters) consumed

The limitation of the estimation presented in figure 4 is that it does not separate different types of fuel in the vehicle stream. Hence, further study is recommended to categorize the total mileage for vehicles according to the type of fuel/energy that they are powered with. A good categorization of distance travelled by the type of fuel that is used by the vehicles in the traffic stream will help in the estimation of each type of fuel that is used.

Using 32.76 cents per gallon as fuel tax (≈ 8.65 cents/Liter), a projection for the resulting effects on the revenue from fuel tax is seen in Figure 5. For this analysis, it is assumed that all vehicles on the road use the same benchmarks that are used for the analysis. The chosen mile per gallon for the analysis begins with 11.9 mpg (5.06 km/l) which is the lowest fuel efficiency for the overall fleet on record, as reported by Sivak and Tsimhoni (2009). Note that the fuel efficiency of various categories of vehicles differs with time. The fuel efficiency for some categories of vehicles as reported by Sivak and Tsimhoni are smaller than (5.06 km/l). CAFE standards showed an interest in evaluating the cumulative means of reaching 35 mpg. This was chosen as the higher end for the analysis. In the analysis for Figure 5, it was also assumed that all vehicles that contributed to the VMT used for the analysis use fossil fuel as an energy source in which revenue from taxes is generated at the point of sale. Figure 5 showed that increased fuel efficiency will result in the reduction of revenue for fuel tax (all other things being equal). This also further supports the fact that to have a reliable financial system for transportation infrastructure, while aiming to achieve energy efficiency, there needs to be a shift to a different form of usage charge system. Recall that the revenue projections for figure 5 are based on the assumption that all the vehicles that contribute to the VMT use fossil fuel. The amount of revenue generated from some vehicles that use fossil fuel may increase with congestion if these vehicles do not have an adequate system to reduce the use of fuel during traffic congestion. The amount of fuel used may also be increased with an increase in idling time for a vehicle. For example, if a car using fossil fuel is being warmed up in the winter time, or a car has the engine running for any reason, for a considerable length of time without being in motion, some energy will be used during this period too. If a considerable portion of the vehicles in the traffic stream uses an alternate form of energy, there certainly will be a reduced revenue from what may have been expected from fuel taxes and various municipalities may come to more realization of the need to take adequate action towards ensuring an equitable, and sustainable road user finance system, as the vehicles that use an alternate form of energy, do not pay fossil fuel tax.

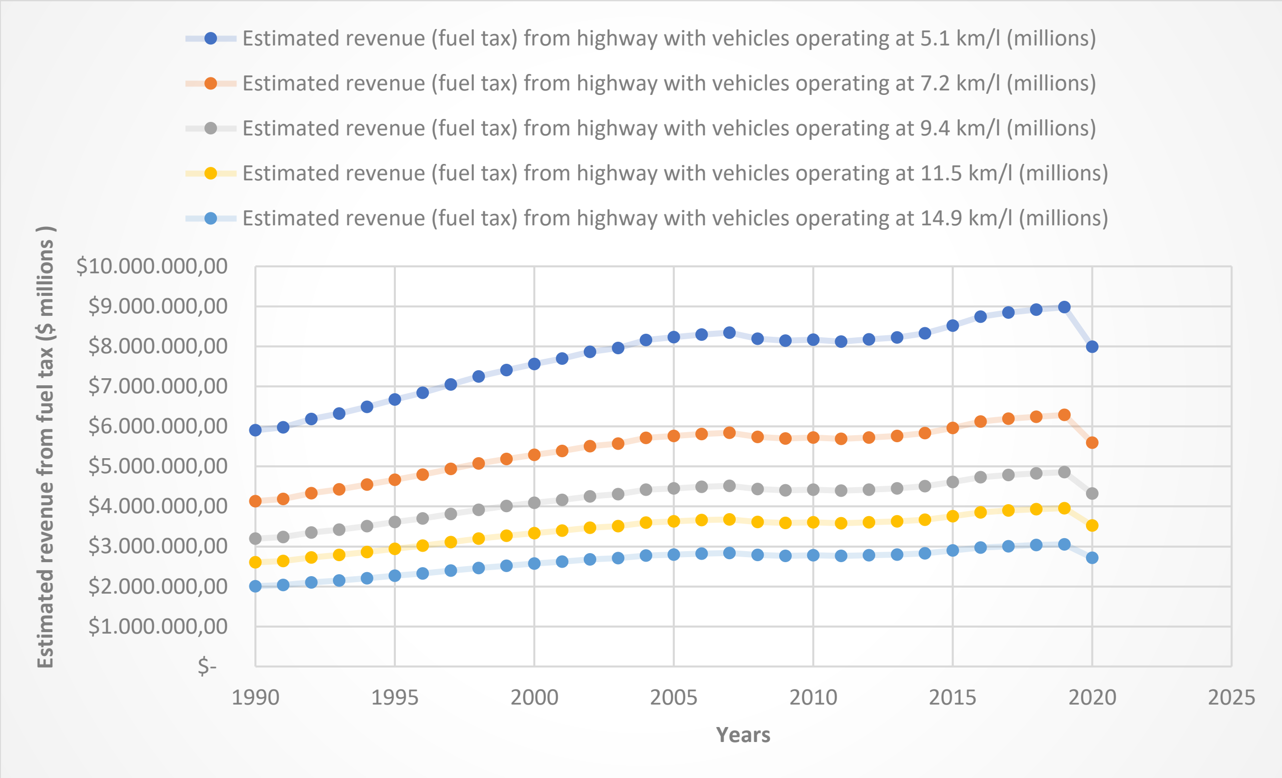

Figure 5 Estimated revenue from fuel tax with improved vehicle's fuel efficiency using 32.76 cents per gallon as a bench mark for fuel taxes

B. 4.2. Road usage fee system for highway vehicles based on Vehicle Miles Traveled (VMT)

Inadequate funding and its adverse effect on the safety and performance of transportation infrastructures is one of the issues that were noted as critical to transportation, by the executive committee of the Transportation Research Board (2013). The report also noted a concern that alternative funding sources may be burdensome for those who cannot afford them. This puts the transportation industry in the midst of two challenges. One of the challenges is to generate a sustainable source of funding for transportation infrastructures. The other is to devise an adequate system to ensure that any funding system for transportation does not price those who cannot afford to pay out of the road. Amidst this challenge also rises the fact that the present reliance on the fuel tax system as a source of revenue for transportation may also be seen as a system that is not equitable. Especially, in any system where those who can afford to buy vehicles that use alternate forms of energy are allowed to skip the 'road usage fee' (fuel tax), but those who cannot afford to buy electric vehicles or any other alternate-energy vehicles are made to continue to pay the fuel tax. It may be said that vehicles that use an alternate form of energy also pay for sales tax during the purchase of the energy to power the vehicle. But it is good to note that the present sales tax for energy usage (like electricity) is not the same as the fuel tax that is paid during the purchase of petrol for automobiles at gas stations. Hence, there is a need to make effort to ensure some equity in the amount that road users contribute to the maintenance fees, regardless of the form of energy that their vehicle is powered with. The issue of fuel tax not being an equitable system of revenue generation in the rise of alternate energy forms of transportation has also called for a review of the present system.

Using a 5 – year window (2015 – 2019), figure 6 below showed the estimated revenue using the fuel tax system (using 32.76 cents per gallon. i.e., 8.65 cents/Liter). This was compared to the National totals of state tax revenue, 4th quarter results (As reported by FRED).

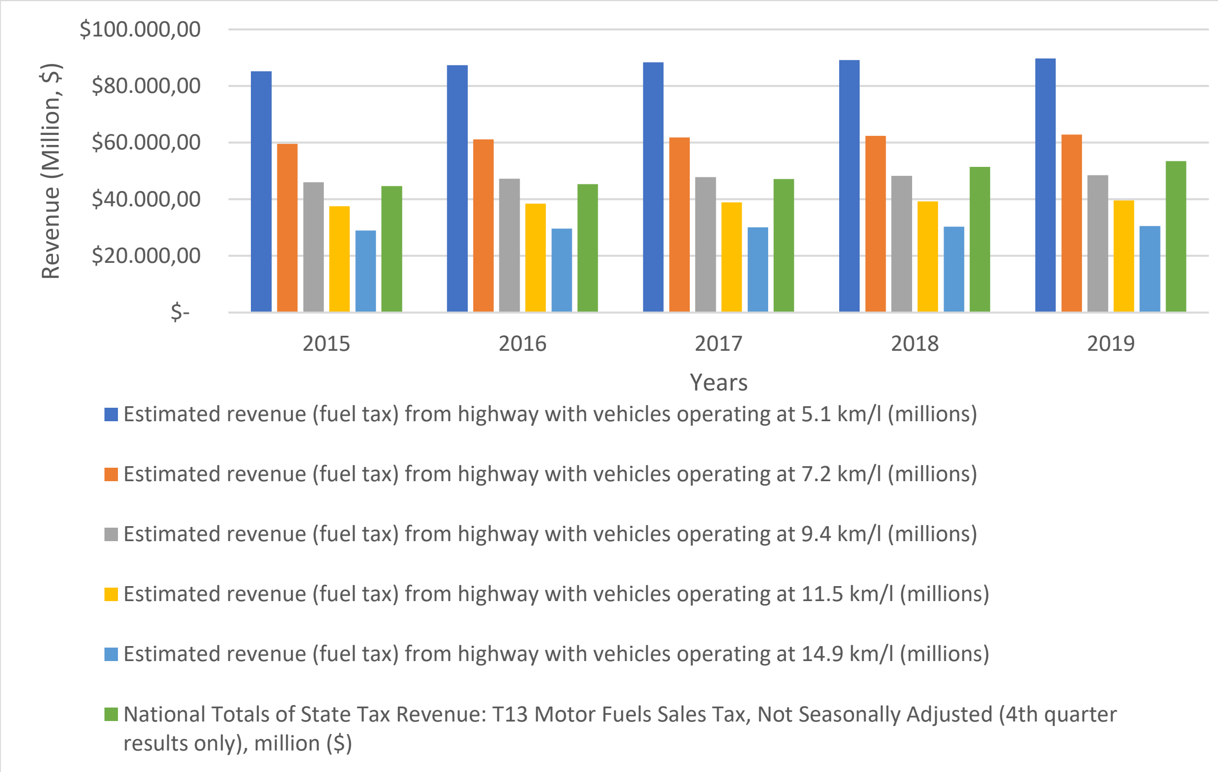

Figure 6 Estimated revenue (million $) from fuel tax with improved Vehicle fuel efficiency (2015 – 2019)

For the most part, infrastructure as a percent of GDP in the US has been on a decreasing progression since around 1970 (Fair, 2021). Peter G. Peterson Foundation (2021) reported that the gas tax was last raised in 1993 from 14.1 cents to 18.4 cents. Because its purchasing power has eroded, America's infrastructure network is suffering the consequences. The Urban Institute reported that 52 billion dollars were collected by states and local governments in motor vehicle fuel taxes in 2019. This does not include any general sales taxes that are levied on motor fuel purchases (in addition to the motor vehicle fuel tax). In 2019, the infrastructure spending for the U.S. is 0.55% of the GDP (Statista, 2023) while the US GDP for 2019 was $21,380.98 billion (Macro Trends, 2023). This puts the infrastructure spending at 0.0055*$21,380.98B = $117.60 billion. Meanwhile, the revenue from motor fuels sales tax in the 4th quarter of 2019 is $53.484 Billion (U.S. Census Bureau, via FRED). If the revenue from motor fuel sales tax alone will be used to finance the infrastructure spending, a shortfall may be noticed in this area (if there is no other revenue from other users of the infrastructure). Hence, to avoid going into a deficit from transportation, it is important to ensure adequate planning for infrastructure construction and maintenance. In places where the revenue for infrastructure maintenance is solely from the motor vehicle fuel tax system, the revenue from fuel tax must be able to cover the cost of maintenance, construction, and associated operational costs (including salaries of workers) involved in the safe movement of goods and services within the community. Figure 6 did not account for the percentage of vehicles that do not pay fuel tax in the revenue estimation. Further study on this is recommended when the percentage of vehicles that do not pay fuel tax sees a significant increase.

Figure 7 showed the difference in the estimated revenue for the same period as that of Figure 6 if the vehicle mile usage fee system is used. Note that 1.64 cents per mile (≈ 1 cent/km) was used in the estimate for the vehicle mile fee system, while 32.76 cents per gallon (≈ 8.65 cents/Liter) was used in the fuel tax estimation. Rather than use the average of the fuel tax for gasoline and diesel (as used for Figure 6), further study is recommended on a more elaborate estimation using the exact proportion of the diesel and gasoline vehicles in the traffic stream (with respect to their rate of fuel use).

If motor vehicle fuel tax alone is to be used to generate the $117.6 billion infrastructure funding mentioned above for the year 2019, with an estimated gallon of fuel at 148,262 million gallons (using an average fuel economy of 22mpg), the fuel tax ($/gallon) expected to meet that revenue can be estimated by dividing the targeted revenue by the expected number of gallons of fuel for the projected travel distance. i.e.,

$$Fuel\ tax\ (\$/gallon) = \frac{Targeted\ revenue\ for\ infrastructure\ spending}{projected\ amount\ of\ fuel\ required\ for\ total\ travel\ distance}\left(\frac{\$}{gallon}\right)$$

$$Fuel\ tax\ (\$/gallon) = \frac{\$117{,}600\ million\ (\$)}{148{,}262\ million\ (gallons)} = 0.79\ \$/gallon$$

The above can also be expressed as:

$$Fuel\ tax\ (\$/Liter) = \frac{Targeted\ revenue\ for\ infrastructure\ spending}{projected\ amount\ of\ fuel\ required\ for\ total\ travel\ distance}\left(\frac{\$}{Liter}\right)$$

In situations where the vehicle-mile-travel system is used, the revenue from the VMT fee must be set at a place that will ensure that adequate funds is available for the safe operation and maintenance of transportation infrastructure.

From Figure 6, the average fuel economy for vehicles in the traffic stream is closer to 22mpg (9.35km/L) for the years 2015 – 2019 (When comparing this with the total motor vehicle fuel tax from state and local governments). In 2019, the total highway miles driven is 3,261,772 million. The fourth quarter revenue for motor vehicle fuel tax is $ 53,484 million. The VMT fees that will be required to achieve this revenue (if all vehicles are on VMT fees) ($/mile) is $ 53,484 million / 3,261,772 million = 0.0164$/mile = 1.64 cents per vehicle mile travel.

Figure 7 compared the estimated revenue using a vehicle-mile travel fee system at 1.64 cents per mile with the varied fuel efficiency of vehicles between 11.9mpg (5.1km/L, lowest value in 1973) to 35mpg (14.9km/L, future interest from CAFE). At 11.9mpg and 17mpg (7.2km/L), the estimated revenue from fuel tax is more than that of the estimated revenue from VMT at 1.64 cents per mile. The estimated revenue for VMT at 1.64 cents per mile (≈ 1 cent/km) is greater than the estimated revenue from fuel tax at 22, 27, and 35mpg (9.4, 11.5, and 14.9 km/L). It is obvious that the vehicle mile travel (usage-charge) system of generating revenue for transportation infrastructure will produce more revenue for the maintenance of transportation infrastructure, as the fuel efficiency of vehicles increases beyond a certain point.

If the VMT fees alone are to be used to generate the $117.6 billion infrastructure funding mentioned above for the year 2019 (mentioned earlier), with a total travel distance of 3,261,772 million miles, the VMT fees can be estimated as follows:

$$VMT\ road\ use\ charge\ \left(\frac{\$}{mile}\right) = \frac{Targeted\ revenue\ using\ VMT\ road\ use\ fee\ system}{Total\ travel\ distance}\left(\frac{\$}{mile}\right)$$

$$VMT\ road\ use\ charge\ \left(\frac{\$}{mile}\right) = \frac{117{,}600\ million\ (\$)}{3{,}261{,}772\ \text{million (miles)}} \approx 0.04\$/mile$$

If only the VMT fee system is used, and there is no reduction in the total travel distance, to avoid a deficit, the VMT fees per mile will be about 3.61 (≈ 4) cents per vehicle mile travel (VMT) to achieve the targeted $117.6 billion infrastructure spending for the referenced year. However, it is important to note that consumers may try to reduce highway travel to reduce VMT cost, hence, the revenue from VMT may not be as expected. If the VMT fee system is widely used, it will be reasonable to allow for some learning curve for a better understanding of consumer behavior and responses to the VMT system. This can be helpful in setting

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the minimum VMT fees for a self-sustaining transportation system (i.e., a transportation system that can finance itself).

Fig. 7 Comparison of estimated revenues from vehicle road usage fee system and fuel tax system (2015 – 2019)

Figure 8 shows a comparison of estimated revenue for 3.61 cents per mile (≈ 2.2 cents/km) and varied vehicle fuel efficiency as above. Figure 8 indicated that the vehicle mile travel system if adequately implemented, is a reliable means to generate a consistent level of revenue for transportation infrastructure that increases proportionately with VMT, regardless of improvement in fuel efficiency of vehicles, vehicle mile (usage charging system) is also expected to ensure that those who use other means of transportation that is not supported by fossil fuels can pay their equitable share.

C. Illustration of VMT based on annual miles driven

The vehicle mile travel based on annual miles driven is a function of the total distance travelled and the VMT fees per mile.

$$VMT\ fees\ based\ on\ annual\ miles\ driven\ (\$) = VMT\ fees\ \left(\frac{\$}{mile}\right)\ x\ Total\ travel\ distance\ (miles)$$

$$i.e., VKT\ fees\ based\ on\ annual\ distance\ driven\ (\$) = VKT\ fees\ \left(\frac{\$}{km}\right)\ x\ Total\ travel\ distance\ (km)$$

Based on average fuel consumption, a previous work assumed the annual vehicle mileage as 13,310 miles (NREL). At 3.61 cents per mile, the annual vehicle road use fee for such vehicle = 13,310 miles x 0.0361 $/mile (i.e., total mile driven for the year x VMT fee/mile driven) = $480.49 annual road user fees. At 1.64 cents per mile, the annual VMT road use fees for a vehicle with an annual mileage of 13,310 miles = 13,310 miles x 0.0164 $/mile = $218.28. If the vehicle does not use fuel that is subject to the fuel tax, an additional road user fee as stated above included with the annual vehicle registration fees will be appropriate. The 3.61 cents per mile is the estimate for the transportation infrastructure expenditure for 2019. The VMT road user fees may depend on the type of revenue that is targeted across the board. Note that this is for illustrative purposes only.

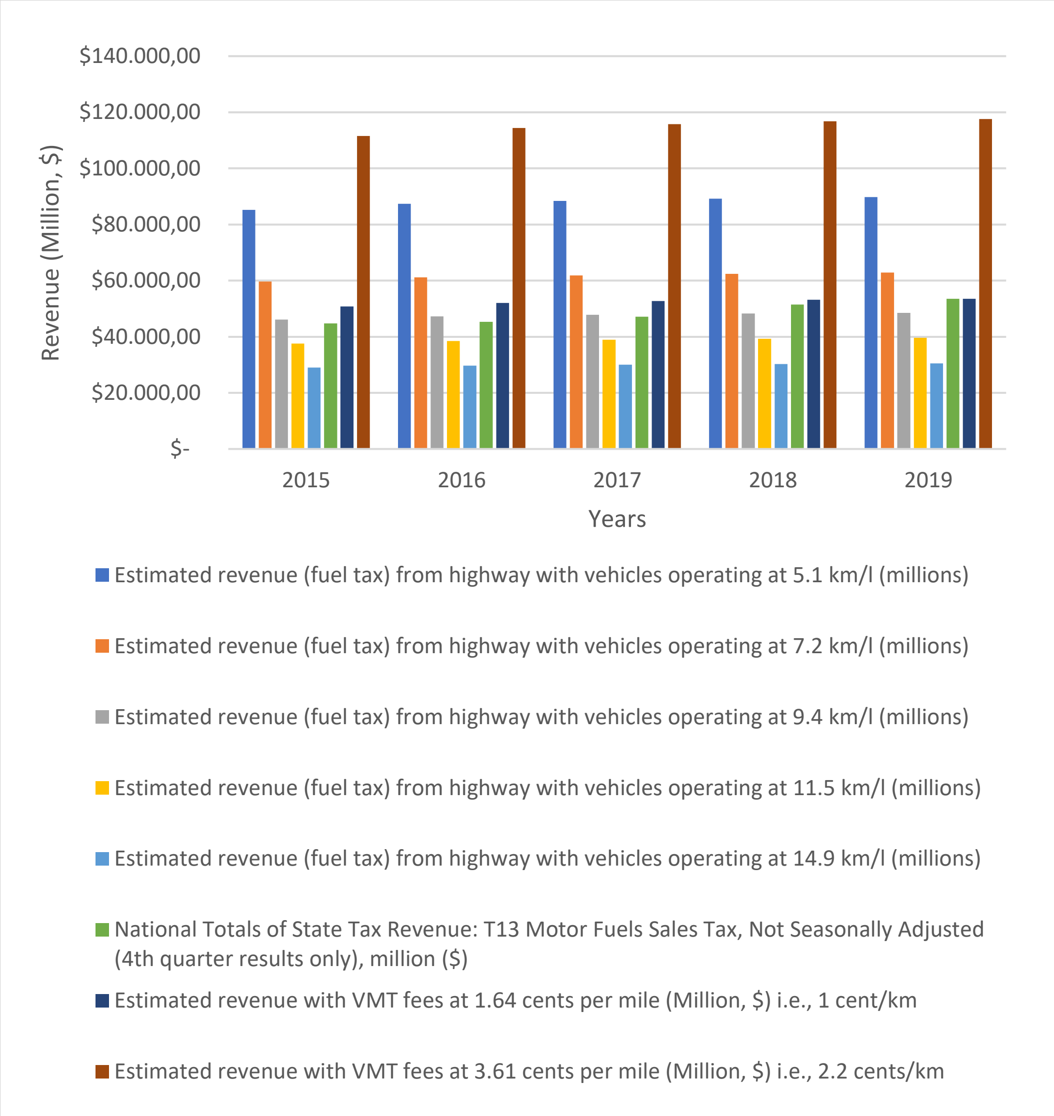

Figure 8 Comparison of estimated revenues from vehicle mile charging system and fuel tax system, using 3.61 cents and 1.64 cents per VMT and 32.76 cents per gallon (8.65c/Liter) of fuel tax (2015 – 2019)

D. Potential means of collecting VMT fees

VMT road user fees can be billed in a variety of ways including periodic billing (monthly, quarterly, yearly, etc).

- Periodic billing: This can be based on an estimate of the expected mileage driven. Vehicle owners can file for a refund based on the actual mileage driven at the end of the year

- Yearly billing: This can be a bill for the previous year (Before registration of the vehicle). For this type of billing system, there may be a requirement for an agreement that when vehicles are sold, the previous owner will be responsible for the bill on mileage driven as shown in the odometer reading at the point of sale.

E. Vehicle mile travel (road usage fee system) and congestion management

It is possible to wonder what kind of relationship can exist between road usage charging systems like the VMT charging system and congestion management. The simple answer is that people are generally cost-conscious. One of the strategies that were identified by Meyer (1999) to improve the effectiveness of transportation demand management (TDM) is to make the cost of travel more apparent to users. In the fuel tax system, it does not appear that the cost breakdown is made very apparent to consumers. Further studies may investigate the following research questions through a survey of people in various communities, "how many drivers know how much the federal tax per gallon of fuel is? how many motorists know how much the state tax (per gallon of fuel) is?" Receiving a road usage fee (bill) for the VMT certainly will make the road usage fee apparent to consumers and may help generate more consciousness for responsible use of road space, to ensure the bill is brought to the minimum. The desire to save more money may result in seeing an increase in the use of an alternate form of transportation. On the other side, if a consumer bought fuel for an automobile, the consumer is aware of the total cost of purchase of the fuel, but the consumer may not pay attention to how much is the additional cost that was included in the purchased fuel, for revenue generation for finance of road infrastructures. The vehicle-mile road-user fee system is a promising way to generate revenue for transportation infrastructures; however, if it is not properly managed, it may not efficiently address the issue of congestion. Charging the right amount for VMT will be a crucial factor when dealing with congestion. Noting that the affordability of the transportation system is important, every municipality will have to decide how much is a fair price to be charged per mile in each community. Implementation of a progressive road usage fee system will be a good idea to explore to ensure that the VMT fee system is not regressive as regards the level of income of the poor. If it will be difficult to implement a progressive fee system, other means to give transportation user-fee rebates to low-income people at various seasons may be adopted in various communities. Various systems may be used to implement a progressive billing system for VMT road-usage fee system. If a periodic billing system is adopted in a community, the billing may be adjusted based on family income for the previous year. The VMT fee system may also be designed to ensure that the system bills the road user based on family income, with consideration for the size of the household. Prepaid systems have been used for various things in various communities; These includes energy usage and telephone system. A similar system in a VMT road usage billing system, (with consideration for family income, and family size at the time of purchase) may help ensure that revenue for road usage is collected upfront, ensure a good cost consciousness of road usage, and ensure that the poor are not priced out of the road. To ensure adequate cost consciousness, any such prepaid planning system should intentionally incorporate systems that make the VMT road usage fee readily apparent to consumers. More research is recommended to evaluate the possible effect of such a prepaid VMT road usage system, and a post-paid VMT road usage system (in which the consumer receives a VMT road usage bill periodically in the mail) on both revenue collection systems, consumer's cost consciousness and choosing of alternative travel modes. Any community that is adopting a progressive road usage system will need adequate planning to determine what will be an affordable and fair amount for various income groups. Note that if it will be challenging to upgrade all the vehicles in the traffic stream to have a VMT-fee system, it will be reasonable to have all new electric vehicles come with a VMT-fee-compatible system. If there is a unanimous decision to encourage people to buy electric vehicles by not introducing any road usage fee for electric vehicles at this time, as the number of electric vehicles in the traffic stream increase, the reality of the need to charge road usage fees for all vehicle may be very evident. At that point, if most of the electric vehicles are already equipped with the VMT road usage fee system, the transition to VMT for electric vehicles will be easier, those who do not have the system may be asked to upgrade their vehicles to VMT road usage fee-compliant status.

If no special equipment or technology is used for the VMT road-usage fee system, the billings can be based on the odometer readings.

F. Generating a sustainable finance system for transportation infrastructures using the VMT system

To ensure that the VMT road usage billing system can generate sustainable funding for transportation infrastructure, without being seen as trying to bring an undue burden to the people, every community will need to be open about the need for transportation improvement, the expected cost to ensure adequate maintenance of the infrastructures in the community and the available funds. There will be a need for community leaders in various places to be able to convincingly explain the needed improvement in transportation infrastructure to the people, and how an increase in the VMT charges may help increase the revenue that is required to meet the target for maintenance of infrastructures in the community. Although there may be a minimum charge that is allowed on a nationwide scale, various communities should be allowed to increase the VMT charges in their jurisdiction (to a reasonable extent) to meet the pertinent need of the community. Price sensitivity reflects how the changes in the cost of a product affect the changes in demand (Investopedia, 2019). According to the law of demand, a relative increase in the price will result in a decrease in the quantity demanded if all other market factors are constant (i.e., there is an inverse relationship between price and quantity purchased). While trying to increase revenue for a certain transportation project, with the knowledge that increases in the VMT road usage fees above a certain limit may result in a decline in the use of the road, and it is not unlikely that a considerable number of people may switch to other modes of transportation, there may be a need to include a slight increase in the cost of other services to ensure balance in the use of the system. This will also require good planning and adequate study of the market. More research on how people respond to changes in transportation costs, and what will be the optimum cost to achieve the desired balance in transportation mode choice, without pricing the poor out of the market is recommended for every community. Sometimes, the volume of traffic on the roads in a community is significantly increased by commercial vehicles in transit to other municipalities downstream. In such cases, it is reasonable that the communities downstream contribute fairly to road infrastructure maintenance and development upstream.

G. Will people be willing to switch to a road user fee system like the VMT fees?

When making transportation policies such as switching to a user fee charging system like the VMT road usage fee system, there is a need to make allowance for anyone who may find it challenging to switch to the new system. There may be a need to have a good review of implementation systems, and lessons learned from states that implemented such systems. For example, the state of Oregon will be a good resource in this regard. The state of Oregon started the program by first doing a pilot program. Oregon's road usage pilot program document (2013) indicated that although the program will be initially for volunteers when the program has convincingly shown its operational success, the legislature intends to add mandatory payers to the system. For any state that wants to embark on a VMT road-use charging system, starting the system using volunteers in various communities (like what was done in the state of Oregon) may be a good idea. There may be a need for collaborations with some designated gas stations to not include fuel tax in the price of gas in the stations, or to designate special pumps that do not include fuel tax for those who enrolled in the VMT road user fee system, while some other pumps will include fuel tax for those who decide to stay with the fuel tax system. Another option that can be used in more pilot programs will be to keep the fuel receipt and have a refund for the fuel tax at the end of the pilot program or at agreed periods. Oregon's road usage pilot program document also envisaged a time that all new cars will have mileage-reporting capabilities. Mileage reporting capabilities in all vehicles will be a good policy to see for a good implementation of the VMT road user fee system. Improvement in fuel pump design in which consumers that are registered for the VMT billing system may tap or swipe a card, and there will be an automatic adjustment on the price to remove the fuel tax for this category of people may also be a good thing to explore to provide reasonable accommodation for anyone that has difficulty in switching to the VMT road usage billing system. Note that the response of people to VMT road usage fees system will affect the amount of revenue that is generated from the VMT road use fees system. This will need to be factored in when setting VMT fees. Further study on how VMT fees affect the choice of driving, the revenue generated from transportation systems, and the impact on congestion is recommended.

H. Addressing the issue of induced demand while expanding road capacity

The development of strategies to create a self-sustainable (self-funded) transportation system is a good endeavor. However, some previous works have shown that there are concerns about induced demand for the use of the road. The term 'induced' implies that a certain condition is indirectly caused by another condition. In the case of the volume of traffic, an improvement to a highway (especially capacity improvements) seemed to be accompanied by more traffic on the road (Lee et al, 1999). The theory of induced traffic has been theorized for more than 60 years and it is now widely accepted among transport researchers. However, oftentimes, in transport modelling, the traffic-generating effect of road capacity expansion is neglected (Naess et al., 2012). New drivers that contribute to induced demand include people who were carpooling, taking transit, not driving or commuting off-peak because they did not want to be stuck in traffic. These change their habits when there is no more traffic (Speck, 2018). With this knowledge, it is important to ensure that adequate measures are taken to keep the volume of road usage at a level to reduce road traffic congestion and its associated negative impacts. However, it is good to remember that new drivers also include those who just got their driving license. Every year, many people in the community reach a stage where they become eligible to drive. Hence, adequate planning for capacity expansion while encouraging the use of alternative modes of transportation and redesigning communities to ensure that people are able to access essential commodities including going from home to work, school, etc. within a reasonably short distance will be commendable.

With the concern about induced traffic, while expanding on infrastructure to reduce traffic congestion, it is important to establish adequate checks and balances in the overall transportation network to ensure that all modes of transport receive incentives that attract a reasonable proportion of users. A road pricing system is such that is expected to create a reasonable check against induced traffic. Hence, it is important to ensure further studies on the behaviour of road users to road pricing. The goal will be to create an optimum price that ensures even distribution of people through all modes of transportation. The report by Volker et al (2020) suggests that environmental analyses frequently fail to completely capture the induced vehicle travel effects of highway capacity expansion projects. Lee (2018) reported that due to the alignment of speed and volume effects, induced traffic may severely compromise the benefit of emission reduction from capacity expansion. When induced travel is underestimated, generally, there will be an underestimation of the environmental impacts and an overestimation of traffic congestion relief benefits that is expected from a highway expansion project. (Volker et al., 2020).

Demand elasticity is a concept that describes the responsiveness of the quantity demanded to changes in price (Lee et al., 1999). Litman (2001) noted that all else being equal, the additional traffic reflects the law of demand that states that as the price (consumer perceived costs) reduces, the consumption of a good usually increases. Koh and Chin (2022) studied driver's trip decisions in response to electronic road pricing rate adjustments in Singapore. Among other things, it was reported that the percentage of new vehicle additions to the average flow was generally higher after price reductions than after price increases. This shows that the induced demand effect on a road corridor can be carefully managed by a careful selection of pricing schemes for road usage. The result also indicated that there are various categories of road users and the pricing effect is different with the categories of road users. At some point, some drivers are priced out of the road. This shows the importance of ensuring careful attention to equity issues in road pricing. It is important to ensure adequate research on the sensitivity of road usage to the economic levels of people in different communities. Road pricing can be set accordingly (with consideration of equity issues).

Cervero (2003) reported that in the United States, claims that induced demand fails to relieve traffic congestion have thwarted road developments. Hymel (2019) reported that estimates that were obtained from the dynamic panel model suggest that highway capacity expansion results in an exactly proportional increase in vehicle travel and that the induced vehicle travel is expected to bring back the traffic speeds to pre-expansion level in about five years. Apart from the concept of induced demand, an increase in the use of the road is expected with growth in the population in different communities globally. Hence, as there is a need for an increase in the construction of decent housing to accommodate the increasing global population, there is a need for adequate planning for the increase in the road capacity for easy movement of people. Similar to the effect of accommodation crises when the proportion of new builds is less than the growth in population if the increase in the road capacity is not proportional to the increase in the number of new drivers, the congestion effect will increase. The negative impacts of congestion will also increase. The fact that more drivers are being added to the roads every year, and the usage of the roads is increasing does not mean that road expansion should be ignored. Ignoring a reasonable increase in road capacity will only create more congestion and its negative socio-economic impacts. However, there is an opportunity for redistribution of usage of transportation facilities in existing transportation modes. For example, there are opportunities to increase ridership in public transportation in various communities around the globe. Hence, there is a need for adequate planning of the transportation pricing schemes.

I. *Managing road pricing, induced demand, and unintended consequences on the price of goods and services*

Road pricing is increasingly seen as a way to improve the allocation of the use of the road among different user groups while improving economic welfare (Thissen et al., 2011). In the pricing schemes, it is important to know that certain businesses will not be severely impacted by an increase in the road pricing schemes as they can easily transfer the increased cost to the consumers when they go to the stores to buy groceries or when customers require certain services. Hence, in places where the prices of goods and commodities are regulated, it is important to give due consideration to vehicles that transport consumer goods as well as to those who render various services to people in the community to avoid unwanted impacts on the consumers. It is no doubt that an increase in the total cost of commodities (including an increase in transportation cost) will result in an increase in the selling price of the commodity. Although Hymel et al., (2010) mentioned that any policy that reduces congestion without an increase in the cost of driving (while diverting some commuters to transit) will tend to attract new traffic that partially offsets the policy's effect on congestion. Verhouef and Rouwendal (2004) reported that a small network model with endogenous car ownership shows that optimal congestion pricing and capacity choice in the whole network may result in more increase in user prices in initially mildly congested areas than in heavily congested areas. The study further noted best efficiency gains may be achieved from a flat kilometre charge under optimal capacity choice. Among other things, Lee (2018) reported that if capacity expansion is accompanied by road user charges, the problem with induced traffic is greatly reduced. However, to avoid unintended consequences on the general cost of living for the entire populace, it is important that the design of road pricing is such that will not bring unintended affordability issues for the poor people in the community through increases to the price of goods and services. Road users who are involved in the transportation of goods and services may receive reasonable discounts that would not cause a negative impact on the ability of the roads to be self-sustainable in terms of ensuring adequate funding for safe infrastructures. If the prices of goods and services increase unnecessarily even though reasonable allowance has been given to these categories of drivers, a government investigation of unnecessary increases in prices of goods and services in the community will be justified.

J. *The use of public transit in the reduction of traffic congestion while addressing accommodation crisis and workforce mobility issues*

The use of public transit is another means of getting more people to their destinations instead of driving alone. Goh (2002) noted that in developed countries, people have gotten so used to mobility through private ownership of vehicles. Meanwhile, public transportation is often perceived as inefficient, inconvenient, or unreliable. Fielding, (1995) noted that for most urban travellers in the US, the automobile is generously crosssubsidized. To reduce congestion, there is a need for municipalities in various places around the globe to further evaluate innovative ways of increasing ridership in public transit. In places where affordable accommodation is becoming a serious issue, it is important to ensure that adequate public transit is available to connect multiple communities. The provision of on-demand transit to connect new settlements (new cities / new villages / new towns, etc.) would be a good way to ensure that rather than having to deal with the issue of accommodation crises, citizens would be able to find affordable transportation to travel to bigger cities to visit friends and families, work, and purchase other things that may still not be immediately available in newer communities. Eventually, the provision of facilities that could be found in bigger cities would be ideal for newer communities. Rather than leave this to the private sector only, government initiative and investment to encourage affordable intercity public transit is a good endeavour to encourage intercity mobility for easy movement of workforce, various goods and services. While it is good to have good studies on the frequency of busses or trains to connect various cities, initial provision of busses at specific times to ensure that people working in another city can get to work on time, and also get back to their homes after work hours would be ideal. In addition, the provision of affordable public transit to connect new settlements to bigger cities at specific times during the weekends would allow people who work during the week to consider making a trip to other cities for shopping and other personal visits during the weekends. When there are reliable transportation systems, people who found work in a community with accommodation crisis may comfortably live and commute from nearby settlements if there is adequate public transit facilities that connects the cities. In addition, the provision of adequate transit facilities would help decrease the need for multiple vehicles on the roads at various times.

K. Encouraging the use of transit

To encourage the use of transit, every community needs to make effort to address the concerns of why a consumer may not want to take the transit. To address the issues of efficiency, and reliability, efforts need to be made to ensure that transit is readily available, and the frequency is sufficient to meet up with demand at various times of the day. Ensuring that the transits (and not only the transit stations) are always maintained in a clean condition may go a long way to not discourage someone that is used to cleanliness from using the transit. If the seats in the transit are dirty, or stained, or if the floor is not well cleaned, this may not be attractive to some users. Seats that are not very comfortable may also not be as attractive as those that are more comfortable. It is good for every municipality to remember that keeping the transit in clean conditions may also generate some jobs for some people, especially if the vehicles are cleaned between trips. Adequate maintenance, upgrade, and replacement of transit vehicles may have some effect on how the transit is perceived. A well-painted transit, and bus station, with good aesthetics, and a good security system may be more attractive to end users than a structure that is not well maintained. Ensuring that security workers are readily available for transit users, ensuring that the cleaning crew goes through the transit periodically after a certain number of trips, or when called upon for cleaning operations will be a good thing. This will help with more job creation in the community. In addition, the high level of cleanliness, comfort, and security in transit is also expected to help increase ridership while reducing congestion. It is also good to ensure that the transit and bus stations can provide adequate shelter against the prevailing weather in the community at various times of the year. Providing alternate mode choices to reach the destination, as well as, ensuring adequate optimization of the trip planning system to minimize the time difference between the use of personal vehicles, and transit may be a good idea. Fielding (1995) also noted that competition between bus and rail could be advantageous. To maintain and enhance transit services, special report 285 of the national academies of science, engineering, and medicine recommends the provision of broad-based tax support for transit systems. The maintenance of a good welfare system in the community to guarantee sustainable jobs, good health care, and an affordable housing system for everyone in the community will be a good endeavor to help reduce the rate of homelessness, and the misuse of the public transit system.

L. *High Occupancy vehicle (HOV) lane, Car Sharing, and High Occupancy/Tolls (HOT)*

Lanes that are restricted for high occupancy vehicles are aimed at providing road users in HOVs with more reliable, and faster travel than those who drive alone during congested periods. It has been noted that many HOVs began as bus lanes or have priority for buses, which are meant to increase the attractiveness and functionality of public transport. Other forms of efficient shared-ride commuting are also allowed on HOV-designated lanes (Schijns 2006). Schijns also noted that experience with the enforcement of HOV lanes on the international level can be deemed successful, but violation rates in some instances are unacceptably high. The case of Los Angeles and Huston with low violation of HOV is supported with a combination of enforcement, a physical provision like barriers, buffers, etc that allow police to properly do their work, and fine levels that are effective as deterrents. Maintaining efficient HOV lanes appears to be a more equitable way of congestion management than high occupancy/tolls (HOT) lanes in which a single occupant can be allowed on the high occupancy lane with a fee. When compared with HOV, HOT lanes may not be seen as a lane that provides fairness to the poor or the less privileged. Although HOT may be used to generate more revenue when the number of HOVs is not as much, HOT also has its disadvantage. In any case, when tolls have to be used, it is important to carefully evaluate options, and provide reasonable and affordable means for those who cannot afford the tolls to be able to reach their destination at a reasonably fast rate.

M. *Employee busing system*

Employee busing system has been used in various communities. Giving incentives to various industries to implement and maintain a company bus system to transport employees to and from work may be a good idea to increase the throughput of people on the roads; while using other systems to discourage the use of personal automobiles to commute to work during rush hour (like an increase in the cost of parking, road-use fees, etc.,), and encouraging all levels of employees either at the managerial level or at the entry-level to use such an employee busing system will be a reasonable idea. Various communities may create a recognition system for industries or offices that have a reasonable ridership for the employee busing system. To encourage the use of the employee busing system by senior management, awards may be given to company owners that commute regularly to work in the company-provided employee busing system.

N. *Alternate day for plate numbers*

Rationing of road space has been identified as a method of reducing congestion (Meyer, 1999). In road space rationing, the number of vehicles allowed in a section of the road can be reduced by various pre-specified conditions, including plate number restrictions for a specific day of the week (i.e., reducing the number of days someone may drive an automobile on a week), but this system also has its challenges. World bank policy research working paper 1554 (1995) noted that “rationing can backfire”. A ban that restricts each car from being on the road on a given workday has seen an increase in total driving and congestion in Mexico City. Many households bought an additional car to increase permits for driving. This kind of system also brings about the challenge of equity for those who cannot afford to buy additional vehicles. An effort to reduce misuse of this system may include making policies that increase the taxes and registration fee on purchase, and licensing for additional vehicles per individual or per household. In addition, the system for rationing road space may be designed to ensure that every individual in the community will always fall in the same rationing group regardless of the number of cars that the individual has.

If road traffic congestion worsens so much, in the midst of resource constraints that limit a proportionate expansion of infrastructures, increasing registration and licensing fees for all vehicles on the road may be another way to explore. This may be combined with an increase in the fees for vehicle mile travel (road usage charge) for automobiles. In a progressive tax system, the increase in fees should be for all vehicles in a way that considers the poor, to ensure equity in the use of public infrastructures.

O. Flexible work hours

A system in which most of the offices, schools and businesses in a municipality resume at the same time makes people come to the road at about the same time. Congestion of roadways could be greatly reduced if offices are encouraged to have flexible resumption times to reduce congestion on the road. This will require a great deal of planning and public education. This system may be efficient if other services that people use also have a great deal of flexibility in the resumption times. For example, if offices have flexible resumption times, it will be a good idea to have daycare centres, schools, and shopping centres that also have flexible resumption, and closing times. Work-from-home options with flexibility in work hours are also expected to help reduce road traffic congestion. A 3-hour interval in the resumption time for a considerable number of employees could result in a significant reduction in the number of people that are off the road at the present rush hour.

P. Establishing an efficient roadway planning system to accommodate the expected usage

Adequate plans to avoid congestion in a municipality should include proper studies of expected population growth and the expected number of road users. Every municipality should ensure that adequate space is reserved for the expansion of roads. For example, if in a municipality, an average household has 2 working adults, and 2 cars and the land area in this community could accommodate 20,000 households; at year X, the number of households in this community is 5,000 households; the roadway planning for a section of the arterial road that was developed for this community can accommodate this household at the rush hour without congestion. If it is forecasted that the number of households in this community will be doubled in ten years and will reach a maximum of 20,000 households in 20 years; If the available road network cannot adequately serve the community when the development reaches the capacity, a good planning system in any community should have a forecast of the number of households (and the number of automobiles per household) that is expected to use the roads in the community, and also make adequate plans for roadway construction that will be able to efficiently serve that community at its maximum household capacity. A good planning system should also include adequate accommodation for a possible increase in the number of automobiles per household.

Q. Ensuring safe, and alternative means of transport exist for vulnerable road users

The creation of safe alternatives for travel is essential in the quest to reduce the effect of congestion in a municipality. The complete street concept is a good idea that seeks to bring people of all travel modes to the roads, ensuring that the roadways can be evenly shared between vulnerable road users and other vehicles on the road. However, there is a need for more work to ensure safety and increase the feeling of safety for vulnerable road users. It is good to always ensure that safe and adequate paths exist for vulnerable road users to connect to various destinations within the municipality. The creation of cycle paths, in which bicyclists and other vulnerable road users have a reasonable degree of protection from high-speed vehicles is a good way to ensure better protection for vulnerable road users.

R. Ensure an even distribution of workplaces throughout the town

The way workplaces are located in a municipality affects the number of people that will use a section of a roadway at a particular time of the day. Looking at the direction of traffic, and the amount of congestion on the roads during rush hours, it will not be difficult to know if a municipality adequately considered the impact of future congestion when making plans for the location of offices, and various business areas. If one direction of a road is frequently congested during the rush hour of the day, it is not unlikely that a considerable portion of the jobs, good schools, etc., in that municipality is located along that route. While it is good to have some offices close to each other, in this age of technological advancement, offices need not be congested in a certain area of the town. There is no need to have most of the offices in the 'downtown' of a city. While it may be a good idea to locate industrial areas for some businesses that have some toxic by-products (pollutants) far away from the city, some other businesses with non-toxic by-products (that mostly operate with computers, pens, and papers, etc.) can be located closer to residential neighbourhoods, and strategically placed at different sections of the town to ensure that the traffic on the roads in a municipality is evenly distributed within the available roads in the municipality at all times, rather than having 1-directional congestion at rush hour of the day.

V. IS IT TOO LATE FOR MUNICIPALITIES THAT HAVE 1-DIRECTIONAL CONGESTION TO MAKE ADEQUATE CORRECTIONS?

It is not too late to correct 1-directional congestion in any municipality. Every community with 1-directional congestion needs to go back to the drawing board and make an adequate travel survey to know why a certain section of the road is congested at a particular time of the day, begin to talk to business leaders about findings that were seen in the report and start giving incentives to redirect the traffic. This may include giving incentives to locate businesses in other sections of the town, physically changing some of the office locations that are under the direct control of the city, (local government authorities) to alleviate congestion, creating satellite offices, embarking on adequate neighborhood redevelopment projects, (this may include rezoning and some reconstruction works to convert some locations that have been used as offices in the past to residential areas, parks, recreational centers, etc.), and putting a limit to the number of new business that can be located within a section of the town until the congestion to that part of the town has seen a significant decline. It is not unimaginable to wish that cars could fly when in a traffic hold-up, (especially during 1-directional traffic congestion in rush hours). However, the flying car concept has a number of issues of concern that will require careful consideration and attention if it will be considered on a large scale in any community. Mofolasayo (2019) presented a report on 'potential policy issues with flying car technology'.

A. Opportunities for further research to avoid future mobility crises given the unintended consequences of the concern about induced demand for transportation facilities

There is no question that road improvement induces an increase in traffic in the United States and abroad resulting in reduced travel time benefits (to some degree). However, the degree of reduction of travel time benefits and what circumstances this reduction in travel time remains a matter of debate. The ability to rationalize road development in the United States has been paralyzed by claims of induced demand (Cervero, 2002). In order to ensure that the construction of new roads to serve the needs of the increasing global population is not hindered by the concern about induced demand and eventually creating serious congestion and mobility crises in different places. Further study is recommended on the optimum size of road network that a community needs for efficient movement of people, goods and services from one point to the other while considering the population of the community.

B. The need to increase research on marketing strategies to encourage the use of alternative modes of transportation (e.g., research on marketing strategies to increase ridership in public transportation)

Traffic engineers, transportation planners, and public officials who are responsible for metropolitan transportation are often criticized for failing to make a dent in congestion. (Taylor, 2002). Meanwhile, the issue with congestion is not only an issue of available road space. It is also an issue about the number of people that have to come on the road at the same time. Hence, there is a need for more coordinated planning and advertisement of the benefits of the different measures to reduce traffic congestion such as the use of public transit, rideshare programs, staggered resumption and closing times for various schools, work, daycare, and shopping centres. Taylor (2002) noted that expanding alternative transportation modes and redesigning cities offer the best long-term means for reducing traffic congestion. It is good to note that expanding alternative transportation modes alone will not automatically result in a significant increase in the number of people who use those alternative transportation facilities. There is a need for efforts to create incentives and promote the use of alternative transportation modes. On the other hand, redesigning cities to bring certain workplaces closer to residential communities rather than downtown areas will help spread the commute throughout the cities. Rather than expecting that people will automatically reduce the use of the roads because road traffic congestion has grown to a frustrating level for many people in a community, further study on marketing strategies to encourage the use of alternate modes of transportation (including public transport and active transport) is recommended.

C. *Multi-variable effects of highway investments and the need for further study to reduce unintended consequences while maximizing the expected positive effects.*

Highway investments result in changes in the functioning of the economy and society as a whole. The highway investment effect can include various factors such as reduction of travel time, noise and exhaust fumes that are suffered by residents that are close to the highway, reduction in congestion on alternate routes due to diversion of traffic to the improved highway, loss of revenue on railroads as a result of substitution effect of railway to highway etc. (Mohring and Harwitz, 1962). Hence it is important to pay adequate attention to highway investment and its subsequent effects on other surrounding factors. While the reduction of travel time is desirable, noise and exhaust fumes that are suffered by residents that are close to the highway are not desirable. Further studies on innovative ways to reduce emissions (without negative impacts on the global economy) and noise that subsequently have negative impacts on residents who are close to new highways are recommended. In addition to the use of trains (both overhead and underground), further studies on the use of underground roads (tunnels) and multilayered roads (e.g., extended bridges) to connect sections of roads that are usually very congested to other parts of various municipalities are recommended. When expansion of cities is necessary. Noise barriers (walls) separating the highway and the communities have been explored in different places. Further study on low-cost noise barriers between highway and residential communities is recommended. Communities should explore adequate expansion opportunities of cities by creating new residences, businesses and essential amenities away from congested municipalities.

Road traffic congestion is indeed an issue that needs attention. However, with adequate strategies, road traffic congestion can be properly managed. In all cases, it will be good to make efforts to ensure that the strategies employed are equitable to all. Humans are made with great potential and could achieve great things if time is used wisely. In this light humanity at large needs to fight the issue of time wastage during traffic congestion in a concerted way.

VI. CONCLUSIONS AND RECOMMENDATIONS

Traffic congestion and its associated cost is an issue that has generated concern for a while now. However, global production of automobiles is on the rise, and it does not appear that there is any desire to reduce the rate of production of automobiles. This makes the issue of congestion on the limited road space one that will continue to pose a substantial challenge to humanity at large except innovative ways are adopted to reduce congestion. This study presents a means to ensure sustainable funding for transportation infrastructure. There is no doubt that as the population grows, there is a need to increase the capacity of the roadways at different times while establishing policies to encourage the use of alternate modes of transport. However, the expansion of the capacity of the roads alone is not the only answer to congestion management. There is a need to ensure adequate measures that complement the capacity of the roads are instituted. This study presents various other techniques on how congestion can be managed. In addition to the issue of traffic congestion, there is a need to ensure that transportation systems in various communities have adequate sustainable finance systems. Among other things, this report presented a simplified method to estimate the road-user fee system that can be applied for vehicles that do not use the fossil fuel tax system. A method to ensure self-funding of the transportation system is also presented for both the fuel tax and the vehicle-mile-travel (VMT) road-user fee system. Strategic methods to improve ridership for public transit in an effort towards the reduction of congestion on the roads are presented. Various congestion management techniques including the use of transit, tolls, restricting the number of days someone may use an automobile

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(using alternate days for plate number system), employing a system that makes the road user-cost apparent to consumers, etc., have been identified as some of the ways to reduce road congestion. The equity issue of road pricing is also a concern as the poor disproportionately pay a higher portion of their income for the pricing systems. In this light, in addition to the establishment of a simplified method for a sustainable financing system for the construction and maintenance of transportation infrastructures, the following recommendations are made to reduce congestion effects while giving due attention to potential equity issues:

- Explore a progressive tax system to ensure that the less privileged do not disproportionately pay a greater portion of their income on congestion tolls.
- Ensure system improvement for transit that will guarantee safe commute of passengers to their destinations within times that will be very close or even faster than the time it will take to use a personal automobile.
- Ensure that public transits provide a good degree of comfort for passengers, and ensure continuous cleanliness, and good maintenance culture for public transit.
- When using congestion toll charges, provide alternative means that can get road users to their desired destination at a speed that is as fast, or even faster than automobiles, to ensure that the less privileged that cannot afford the toll have another option to avoid delay due to congestion. An example of an alternative means to beat congestion is the light rail transit (LRT) which is not usually stopped by traffic lights at road intersections. The well-connected bus system that is given adequate space allocation priorities on the roads may also be a good option to explore in more localities.
- Implement a vehicle mile travel (road-use pricing) system as a means of generating an equitable source of revenue (for transportation infrastructures); considering the fact that some vehicles are supported by energy systems that are not subject to higher taxes like fuel tax.
- Ensure that communities are designed to allow the location of some workplaces, schools, supermarkets, and other essential amenities to be within reasonable commute distance to people's residences to reduce travel distance and congestion of the roads at peak hours.
- Explore transportation tax rebate options for the less privileged and the poor whenever conditions arise in which it is difficult to address equity issues at the point of use.
- Implement a policy in which all new automobiles will be equipped with an automatic vehicle mile travel reporting system.
- Device applicable regulations to limit car breakdowns on the road in all jurisdictions and ensure a fast and efficient response to clear the roads during car breakdowns or traffic crashes. This may include technological improvement to periodically communicate the health of vehicles to the owners, the vehicle manufacturers, and the law enforcement officers, and subsequently, ensuring that appropriate actions are taken in that regard (to keep vehicles that are likely to break down off the roads).
- Ensure adequate preparedness, and consistent, and efficient road maintenance services in all jurisdictions to make way for smooth traffic flow during adverse weather conditions like snow, rain, etc.

Given that according to the law of demand, an inverse relationship exists between price and quantity demanded, it is envisaged that the VMT road usage billing system can be used to regulate the number of cars, and subsequent congestion on the roads. With knowledge about high elasticity or inelasticity of demand, more research is recommended in this area to determine consumer behaviour with various VMT pricing systems, and how a system like this may be best applied to address the issue of road congestion. The report also presents research insights that could be further explored for the effective implementation of alternative road-user fee systems.

A. Limitations

The estimation of 1.64 cents per mile for vehicle mile travel (VMT) fees for the year 2019 is with the assumption that the revenue generated by the federal government from motor vehicle fuel tax is included in the records for state and local governments. If additional data is available in the future that gave separate numbers for the revenue that is generated from the fuel tax records for state and local government, further study is recommended to include the applicable revenue from the federal government in the estimation of the VMT road-user fee. In addition to illustrating techniques for establishing a vehicle-mile-travel (VMT) road finance system for vehicles that do not pay fuel taxes, this study presented a simplified method for establishing a self-funded transportation system. The analysis presented in this report is for illustrative purposes only. Further study is recommended on this for adequate planning for a self-sustaining transportation infrastructure system for every country (especially as the rate of use of roads as well as the need for infrastructure maintenance and construction change from one year to another).

DATA AVAILABILITY STATEMENT

Relevant references to data that is used in the study is provided in the manuscript.

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Upravljanje cen prometnih zastojev, s tem povezanih vprašanj lastniškega kapitala in vzpostavitev trajnostnega financiranja prometne infrastrukture

Povzetek - Zastoji v cestnem prometu, ki so delno posledica neučinkovitih načrtov rabe prostora in neustreznosti obstoječe prometne infrastrukture za prevoz ljudi po istih poteh, predstavljajo izziv. Neustrezno financiranje prevoza omejuje število cest, ki jih je mogoče zgraditi za povečanje zmogljivosti prometnega omrežja. Zaračunavanje zastojev v cestnem prometu je bilo opredeljeno kot način zmanjševanja zastojev, saj poveča stroške potovanja uporabnikom, vendar obstaja zaskrbljenost zaradi vprašanj lastniškega kapitala za tiste, ki si morda ne morejo privoščiti te cene. Za ponazoritev je bila narejena tudi primerjava prihodkov, ki bi jih lahko ustvarili (ob drugih pogojih), z uporabo sistema določanja cen prevoznih kilometrov (CPK) v primerjavi z davkom na gorivo, za 5-letno obdobje. V raziskavi je bilo ugotovljeno, da je sistem določanja cen „prispevkov za uporabo cest“ CPK uspešen način in tvori predstavlja osnovo za pravičnost med tistimi, ki uporabljajo vozila na fosilna goriva, in tistimi, ki uporabljajo alternativno energijo. Poleg predstavitve poenostavljenega postopka za vzpostavitev trajnostnega sistema financiranja prevoza je ta študija predstavila tudi poenostavljeno metodo za oceno ustreznega davka na gorivo in uporabnine cest za doseganje samoplačniškega prevoznega sistema.

Ključne besede - tehnike določanja cen zastojev, izdaje lastniškega kapitala, davek na gorivo, trajnostno financiranje prevoza, pristojbina za uporabo cest CPK