2. LITERATURE REVIEW

2.1 Introduction

Road transport is an essential element of the Sri Lankan transport network, and enabler of the Sri Lankan economy and society. However, a number of externalities arise from motor vehicle usage on roads, including pollution, congestion and road traffic accidents. Motor vehicle activity levels are characterized in terms of traffic volume or vehicle–kilometers travelled (VKT). Total VKT provides a proxy measure of the overall pressure on the environment from all forms of road transport (NZ Ministry for the Environment 2009). Annual VKT at the national level can be defined as the number of kilometers travelled in a country by all vehicles during a one year period and it is expressed as follows

\[ \text{VKT} = \text{Number of Vehicles} \times \text{Distance Travelled} \] (EIA 2005)

Fort Collins LUTRAQ Team (2001) stated that however, the estimation of VKT is not as straightforward as the traffic flow. VKT has always been a difficult indicator, because it is not measured directly, rather it is always estimated.

Kumapley and Fricker (1996) pointed out that VKT estimation methods can be classified into two broad categories i.e traffic measurement methods and non–traffic measurement methods. Under these two broad categories, there are four basic methods. Traffic measurement methods are of two types, e.g. odometer readings (vehicle-based method) and traffic counts (road-based method), while non–traffic measurement methods consist of household/driver survey method and fuel sales method.

Since estimates of VKT are used extensively in transport planning for allocating resources, estimating vehicle emissions, computing energy consumption and assessing traffic impact, the estimation of VKT of Sri Lanka is important for planning purposes, environmental monitoring, accident analysis, highway fund allocation, trend extrapolation, and estimation of vehicle emissions. In addition, VKT is the best available measure of exposure with which to transform fatalities into a rate (i.e. the number of deaths per billion vehicle kilometers driven). Furthermore, VKT estimates can also contribute information necessary to inform infrastructure investment decisions and road safety policy. Due to its importance to policy decisions, it is critical to have accurate estimates of VKT.

An increase in vehicle kilometer travelled can be due to several factors – more people, more vehicles in the fleet and more individual travel. These three factors have combined to steadily increase total VKT.
Generally speaking, a growing population is accompanied by a growing number of vehicles. As population grows, so too does the total distance travelled by road, unless balanced by a significant drop in the distance each person drives. Increase of vehicles leads to increased access to transport, an increase in total VKT, and can lead to greater congestion on our roads. More greenhouse gas emissions are produced for each kilometer travelled on congested roads. Greater vehicle numbers also lead to greater waste in terms of used oil, batteries and tyres, and greater numbers of scrapped vehicles.

2.2 Models Developed to Calculate VKT

Kumapley and Fricker (1996) stated that VKT estimation methods can be classified into two broad categories—traffic measurement methods and non-traffic measurement methods. Afzal Hossain and David Gargett (2011) pointed out the traffic measurement VKT estimation methods are more preferable than the non-traffic measurement methods.

2.3 Traffic Measurement Methods

2.3.1 Odometer Reading Method

Odometer readings are the only regular records of accumulated travelled distances for the majority of vehicles, making the calculation of the exact number of kilometers driven within a given time period possible. At regular vehicle inspections, the average distance travelled by the vehicles is determined and then multiplied by the number of road vehicles. (Afzal Hossain and David Gargett, 2011)

2.3.1.1 Advantages

This method provides a more accurate record of the total distance travelled, by all vehicle types, within a given year. (Afzal Hossain and David Gargett, 2011).

2.3.1.2 Disadvantages

Afzal Hossain and David Gargett, (2011) stated that Odometer readings do not allow any association with geographical data regarding where these travelled distances are made. Due to this disadvantage, other sources of information are used to estimate VKT by region or road class.

In addition to that they pointed out there are several other disadvantages of this method, including the possibility of reading/reporting errors, notation/transcription errors, odometer
tampering (i.e. modification of odometer records), and vehicle drop-out caused by accidents or aged vehicles.

2.3.2 Traffic Counts (Road-Based Method)

The annual VKT estimation models based on traffic counts use the data collected on a sample of monitored road sections to estimate the VKT of the entire network. Traffic flow, usually represented by the Annual Average Daily Traffic (AADT), and length of the sampled road sections are the main variables used. To annualize this value, it is multiplied by the number of days in a year. In estimating VKT using traffic counts, it is customary to assume that a vehicle counted on a section of road travels the entire length of the section. Under this method, some vehicles travelling only a portion of the section will be counted while others will not, depending on whether they cross the counting location. (AfzalHossain and David Gargett, 2011).

2.3.2.1 Advantages of Traffic Count Method

This traffic count method has several advantages. It allows the disaggregation of VKT by type of road, vehicle attributes, time periods or regions (AfzalHossain and David Gargett, 2011).

2.3.2.2 Disadvantages of Traffic Count Method

This type of model does not allow the estimation of VKT by type of driver or trip motivation. Also, as they are usually based on a spatial and temporal sample of counts, sampling errors and instrumental and other counting errors must be carefully analyzed. (AfzalHossain and David Gargett, 2011).

2.4 Non-traffic measurement methods

The non-traffic measurement methods for estimating VKT use non-traffic data, such as socioeconomic data, including fuel sales, trip-making behavior, household size, household income, population, number of licensed drivers, and employment. Only two methods, i.e. household/driver survey and fuel sales, are discussed below.
2.4.1 Household/Driver survey method

In this method, a questionnaire is sent every year to thousands of households (owning one or more cars) which are requested to provide various information; the number of kilometers driven by each vehicle during the whole year. (AfzalHossain and David Gargett, 2011).

VKT estimation models based on demographic and socioeconomic characteristics usually require extensive data including:

- Population, employment and land use data
- Personal and household characteristics, such as income, household composition, vehicle ownership and licensed driver status
- Personal and household travel characteristics, as determined from household travel surveys, such as average annual miles driven per licensed driver by sex and age cohorts, average annual household VKT by area type, household and personal trip-making behavior. These models assume a constant driving pattern over a period, say five to six years, and require only the annual change in licensed drivers or household population for the estimation and forecasting of VKT. Estimates of average annual kilometers driven per licensed driver or household are either collected by asking the respondents to guess the amount of travel they do, or to extrapolate the difference between two odometer readings of a vehicle taken over a period. VKT is then calculated by multiplying this estimate of average annual mileage per household unit (or licensed driver) by the population of households (or licensed drivers). (AfzalHossain and David Gargett, 2011).

Prof. Amal S. Kumarage, (1992), carried out the estimation of VKT in Sri Lanka by roadside interview. A sample data collection was done to obtain the annual kms operated by a particular vehicle along with its operational characteristics such as ownership, age (series) and type of usage. In order to do this a team of surveyors was trained and dispatched to Colombo and Kandy. The surveys were done during the period March 19 to April 12, 1992. In this method, drivers of vehicles parked along the road sides were interviewed, the drivers of vehicles arriving at the petrol stations were interviewed, and company records were used. Petrol Vans have a significantly lower annual kms than the diesel counterpart. In the case of Lorries, which are engaged in long distance haulage were found to have a significantly higher mean annual kms of 41800 whereas other Lorries averaged only 16900kms. In the case of buses, a similar relationship was observed for the vehicle in long distances routes which were
doing 21100 kms more than vehicles in other routes. It was also established that minibuses averaged only 29900kms per year when compared to the 46 700kms by the larger buses.

2.4.1.1 Dependent variable of the model

The number of Vehicle Kilometers Travelled (VKT) is obtained from the Household Travel Survey (HTS) as the total road distance travelled by each household for all trips where the mode is vehicle driver. When the dependent variable VKT was fitted, one of the assumptions of linear regression (the requirement for the errors to have constant variation) was violated. A simple square root transformation fixed this problem. Therefore, the recommended model has the square root of VKT as the dependent variable. To predict VKT, we merely square the output from the model. (Grace Corpuz, Michelle McCabe and Kamila Ryszawa 2001)

2.4.1.2 Predictor variables of the model

The initial set of predictor variables that were tested were jointly chosen by TPDC (Transport and Population Data Centre) and the Sustainability Unit. These variables measure three main characteristics: location, socio demographics and urban form / neighborhood design. (Grace Corpuz, Michelle McCabe and Kamila Ryszawa 2001)

2.4.1.3 The recommended model

The recommended model is represented by the following linear equation relating the square root of VKT to a number of significant predictor variables.

\[
y = a + b_1x_1 + b_2x_2 + \ldots + b_nx_n
\]

\[
\sqrt{\text{VKT}} = 3.920 + 2.4510*A + 0.0124*B - 1.8057*C - 0.0021*D - 0.0099*E + 0.0084*F
\]

(Grace Corpuz, Michelle McCabe and Kamila Ryszawa 2001)

Where \(\sqrt{\text{VKT}}\) - Square root of the household

A - Number of vehicles
B - Closest distance to major center or CBD
C - Land use mix
D - Local employment
E - Housing density
F - Distance to nearest Train, ferry, light rail or high frequency bus)
2.4.1.4 Limitations of the model

The regression model makes predictions of VKT for given values of the explanatory variables in the model. These predictions are subject to errors because of the imperfect fit of the model which can predict three quarters but not all of the variability of (the square root of) household VKT. Users should be mindful of this limitation when using the predictions on their own for say, inputs for another process. But for the purpose of comparing predictions, such as between locations which is main purpose of the model, the errors of the predictions become less of an issue. The comparisons remain valid because of the use of a single model as the same basis, and especially since the errors have constant variance and do not vary systematically between predictions. (Grace Corpuz, Michelle McCabe and Kamila Ryszawa 2001),

2.4.1.5 Advantages

Using this method, it is possible to reach a high level of detail and flexibility in the collected data. (Afzal Hossain and David Gargett, 2011)

2.4.1.6 Disadvantages

There are several disadvantages of this method. These include: low response rates, inconsistent data, sampling errors, response bias and estimation errors and high implementation costs (Afzal Hossain and David Gargett, 2011)

2.4.2 Fuel sales

In the USA, fuel sales have been adopted for VKT estimation for over half a century. However, there is no documentation of the actual procedure used. The use of fuel sales to estimate state VKT is not new in Australia. (Kumapley, 1994)

The volume of road traffic (i.e. VKT) is estimated from information about fuel supply and fuel consumption, as derived from estimates of kilometers driven per liter of fuel for typical types of vehicles (Leduc 2008). Regression, logic, and other model types have been developed for VKT estimation based on fuel use and sales; however, a ballpark estimate of VKT can be generated by dividing the total number of liters of fuel sold by the fleet fuel economy, in kilometers per liter (usually expressed as l/100km). VKT can be estimated from a simple equation which is shown below (Fricker and Kumapley, 2002):
VKT = TNL (fuel use) / FKMPL (fuel intensity) (2.1)
Where VKT = annual vehicle kilometers travelled;
TNL = total number of liters of fuel sold (petrol, diesel and LPG);
FKMPL = total fleet kilometers per liter, In other words, kilometers = liters / (kilometers per liter).

In the context of transport, ‘fuel intensity’ more commonly refers to the energy efficiency of a particular vehicle model, where fuel intensity is given as a ratio of distance units per amounts of input fuel (petrol, diesel, LPG, etc). In Australia, this ratio is measured as liters per 100 kilometers (Liters per 100 km).

2.4.2.1 Advantages associated with the fuel-based VKT estimation model
The fuel-based VKT estimation model is very useful for several reasons. The fuel-based method estimates total area-wide VKT and provides an estimate for each year (LUTRAQ Team 2001).

Another advantage of this method is that it does not require travel distances (Azevedo and Cardoso 2009).

2.4.2.2 Problems associated with the fuel-based VKT estimation model
Even though the fuel sales method is very useful when there is no record of travelled distances, it has some important limitations, such as the need for multiple data sources and the need for several assumptions in the estimation of average fuel consumption (Azevedo and Cardoso 2009). The errors associated with the VKT estimation are dependent on the accuracy of retail fuel sales data and the fleet fuel efficiency figures used (Kumapley and Fricker 1996). However, the estimation of fleet fuel intensity, in liters per kilometer (LPKM), presents the most difficult problem for fuel-based VKT models. The LPKM depends on the following: fleet age mix, condition or state of the vehicle, driving patterns and habits, weather, topography, fuel loss in motion (evaporation, spillage, etc). Improvements in combustion technology, together with legislation on emissions, complicate the estimation of fleet fuel economy. Manufacturers’ claims of fuel economy may not be representative of fleet economy due to driving and other characteristics. Commercial vehicles (trucks) have lower fuel efficiency than automobiles and light trucks. Data are currently not available to facilitate the estimation of fleet (all vehicles) fuel economy. Due to differences in the unit price of fuel
across the country, drivers tend to buy fuel in states with lower fuel prices during interstate travel, thus estimation of the amount of fuel bought in the state, used for travel on state roads is even more difficult to estimate.

2.5 Definitions Related to Calculation of VKT

Daily vehicle kilometers travelled are calculated by multiplying the observed 24-hour average annual weekday traffic volumes by the single center-line length of the primary roadways within city limits only. (The City of Calgary Transportation Planning, 2010)

Annual vehicle kilometers travelled are calculated by multiplying daily VKT with a daily-to-annual conversion factor for each year. (The City of Calgary Transportation Planning, 2010)

As daily VKT represent a 24-hour weekday traffic volume, a daily-to-annual factor is used (not simply 365) to estimate the annual VKT.

A formula for the annual VKT calculation is given below:

\[
\text{Annual VKT} = \text{Daily VKT} \times \text{Daily-to-annual factor}
\]