ESTIMATION OF VEHICLE KILOMETERS TRAVELLED IN SRI LANKA

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Declaration

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Abstract

Vehicle kilometers traveled (VKT) is the total kilometers traveled by motor vehicles on the highway system during a given period (particular year). Vehicle kilometers traveled by passenger automobile is an important factor in Transport planning, allocating resources, estimating vehicle emissions computing energy consumption, assessing traffic impact, analysis of accidents (i.e. the number of deaths per billion vehicle kilometers driven) Infrastructure investment decision and to make policy decisions.

In this report VKT is calculated by multiplying of vehicle factor, total fuel sale volume, and fuel consumption rate. Vehicle factor was estimated by dividing the fuel usage each vehicle type by total fuel usage. In order to estimate the vehicle factor, initially vehicles are classified, based on the Petrol and Diesel vehicles and prepared the Survey form in order to collect the fuel usage data and fuel consumption rate. By analyzing the collected data, vehicle factor and average fuel consumption rate were determined for each vehicle type. Since direct measurement of vehicle kilometers traveled has never been used, the several assumptions have been made in this study.

VKT has been calculated for each vehicle type for the year 2012 based on survey carried out in the year 2012. Considering the 2010, 2011and 2012 fuel sale data, fuel sale growth factor is calculated for the year 2013 and 2014. VKT has been estimated for the year 2013 and 2014 for each vehicle type assuming the vehicle factor is used in 2012 is same for the year 2013 and 2014.. In similar manner VKT for each vehicle type can be determined for the future years, Fuel consumption and fuel sale data can be obtained for each year and vehicle factor need to be estimated since it may not be same for each year. Therefore in this report illustrates the methodology to find the minimum no of survey location for estimation of vehicle factor at a 95% of accuracy. It was found that Motor Cycle factor for Colombo District can be estimated using eight number of Survey locations.

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1. INTRODUCTION

1.1 General

Vehicle kilometres travelled (VKT) is the total kilometres travelled by motor vehicles on the highway system during a given period.(Particular year.) Vehicle kilometres travelled by passenger automobile is an important factor in Transport planning, allocating resources, estimating vehicle emissions computing energy consumption, assessing traffic impact, analysis of accident (i.e. the number of deaths per billion vehicle kilometres driven) Infrastructure investment decision and to make policy decisions.

Transport is a vital link that brings people and goods together across a country. People rely on it to get to work and for educational, social and recreational activities. Transport also connects suppliers to markets and helps showcase our natural environment through tourism.

Road transport is the dominant mode of transportation in Sri Lanka. While it provides many economic and social benefits, it also has environmental and health impacts. For example, road transport is a primary source of harmful air pollutants in some urban areas. Waterways can be affected by contaminated run-off from roads, and wastes such as used oil, batteries and tyres require careful disposal.

It is difficult to quantify the actual environmental and health impacts, number of accidents, of road transport at the national level. However, the distance travelled on our roads (also known as vehicle kilometres travelled or VKT) is a good proxy for the pressure road transport puts on the environment. This measure is widely used internationally to assess the magnitude of the pressure and how it is changing over time.

By understanding the total distance travelled on Sri Lankan roads, the types of vehicles we use, and fuel type and how intensively we are using our road transport, we can learn more about the pressure on road transport is placing on the environment, the expenditure spent on roads. As the growth of the economy the VKT factor for a country and area changes. To conclude about the other related measures the VKT should be calculated accurately every year.

For a developing country like Sri Lanka, very expensive to carry out the surveys on island wide for estimation of VKT for each year. T

he same expenditure cannot be allocated to calculate the annual VKT every year. With this condition the research focuses on predicting the future VKT with the developed model.

1.2 Objectives

- The main objective of this research is to estimate the VKT in Sri Lanka and to develop a model to predict the VKT factor in the future years
- The sub objectives of the research are to calculate the vehicle factors in province vise, in Petrol Diesel vise and in Vehicle type vise.

1.3 The Methodology

To achieve objectives following methodology was adopted.

- The vehicles in Sri Lanka were classified (1)Motor Cycles, (2) Three wheelers, (3) Cars, (4) S/Wagons, (5) Pick Up, (6) Jeep (7)Pajero, (8) Passenger Van, (9) Goods Van, (10) Mini Bus, (11) Bus, (12) Light Truck, (13) Medium Truck, (14) Large Truck, (15) 3 Axle Rigid Truck, (16) 3 Axle Art'd Truck., (17)4 Axle Art'd Truck., and (18) Hand Tractor
- Collected the fuel volume pumped for each type of vehicle from 6:00 am to 6:00pm in selected fuel stations covered in all roads in Sri Lanka.
- The total fuel volume was obtained for the each district in Petrol and Diesel separately.
- The proportion of the each vehicle type was found by dividing the total fuel volume pumped for each vehicle in the district by the total fuel pumped for all the vehicles in the district
- Vehicle Kilometers Travelled was found for each vehicle type for each district, each province and island wide.
- To predict the future VKT, vehicle factor, Fuel usage, Fuel consumption rate are required, and in order to find vehicle factor, hypothesis analysis was carried out to find the minimum no of survey points which has 95% accuracy.

1.4 The Scope of the Research

Chapter 2 presents a detailed literature review covering the main topics related to the research.

Chapter 3 illustrates the proposed methodology for calculating the VKT for the base year.

Chapter 4 illustrate the analysis of the data collected on the fuel consumption by different type of vehicles in Sri Lanka and the conclusions made on the results.

Chapter 5illustrates the developed methodology to find the future VKT.

Chapter 6 illustratesthe developed methodology to find the future VKT.

Chapter 7 illustrates the Conclusion of the Research

Chapter 6 illustrates the future work that can be done with the base of this research.

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

VKT = Number of Vehicles × 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 thatVKT 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 thatVKT estimation methods can be classified into two broad categories—traffic measurement methods and non-traffic measurement methods.AfzalHossain and David Gargette (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. (AfzalHossain 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. (AfzalHossain and David Gargett, 2011).

2.3.1.2 Disadvantages

AfzalHossain 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 road side 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 House hold 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 KamilaRyszawa 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 KamilaRyszawa 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 variables2.

$$y = a + b1x1 + b2x2 + \cdots + bnxn$$

√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 √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 5 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 KamilaRyszawa 2001),

2.4.1.5 Advantages

Using this method, it is possible to reach a high level of detail and flexibility in the collecteddata. (AfzalHossain 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 (AfzalHossain 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 of liter 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 CalgaryTransportation 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 CalgaryTransportation Planning, 2010)
As daily VKT represent a 24-hour weekdaytraffic 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:

Annual VKT = Daily VKT x Daily-to-annual factor

3. THE PROPOSED METHOD FOR CALCULATING THE VKT

VKT is calculated by multiplying of vehicle factor, total fuel sale volume, and fuel consumption rate. Vehicle factor was estimated by dividing the fuel usage each vehicle type by Total Fuel usage. In order to estimate the vehicle factor, initially vehicles are classified, based on the Petrol and Diesel vehicles and prepared the Survey form in order to collect the fuel usage data and fuel consumption rate. By analyzing the collected data, vehicle factor and average fuel consumption rate are determined for each vehicle type.

Therefore following equation was used for calculating the VKT.

Annual VKT (km)= Vehicle Factor x Fuel Usage (l) x average Fuel Consumption rate (km/l)

Vehicle Factor = Fuel usage by particular Vehicle/Total Fuel usage (Annex V)

Total Fuel Usage (l) = Obtained by fuel sale data from IOC and CEYPETCO for the year 2012 (Annex VI)

Average Fuel Consumption rate = Obtained from collected Survey data (Annex III**)**

3.1 Sample Calculation for the Base Year 2012

3.2 Calculation Steps

Step 1:

Vehicle factor was calculated from the collected data(Annex V)

Step 2:

The fuel sales data is obtained from IOC and CEYPETCO for the year 2012 (Annex VI)

Average Fuel consumption rate (km/l) for each vehicle type for each province was obtained from the survey data. (Annex III)

Step 4:

VKT has been estimated using following equation.

VKT (km)=Vehicle Factor x Fuel Usage (l) x average Fuel Consumption rate (km/l)

3.2.1 Sample Calculation for Motor Cycles in Colombo District

Step 1:

Total Petrol Consumption per day in Colombo division by all types of vehicles (From Collected Data) = (5312.01+7352.73 + 47165.70 + 18534.53 +3610.00 +4495.46)*1.2

= 47,165.70

(Refer table 3.1) and where Night time factor -1.2 (Annex IV)

Total Petrol Consumption per day in Colombo division by Motor Cycles = 5312.01

Motor Cycle Factor for Colombo division = 5312.01/ 47165.70 = 0.14

Similarly the motor cycle factor obtained for Avissawella division is 0.28.

The average motor Cycle factor for Colombo District = (0.14+0.28)/ 2 = 0.21

Step 2:

Sales data for petrol stations obtained for the year 2012 from CEPETCO and IOC for Colombo district = 274144107.6 liters

Step 3:

Average consumption rate for motor cycles obtained from the survey data = 55.09 km/liter

Step 4:

VKT for Motor Cycles in Colombo District for the year 2012 = 0.21 x 274,144,107.6 x 55.09

= 3,166,298,052km

Table 3.1: Calculation of Motor Cycle Factor

			Petrol Usage					Total Petrol Pumped Per Day (6)=1.2* (1+2+3+4+5)		
Province	**District**	**EE Division**	**Collected Data for Motor Cycles (1)**	**Collected Data for Three wheelers (2)**	**Collected Data for Cars & S/Wagons (3)**	**Collected Data for Jeep &Pajero (4)**	**Collected Data for Passenger Van (5)**		**Motor Cycles (7) =1/(6)**	**Average for the District**
Western Province	Colombo	Colombo	5312.01	7352.73	18534.53	3610.00	4495.46	47,165.70	0.14	0.21 (0.14+ 0.28) /2)
		Avissawella	9492.375	10289.96	10687.63	1746.90	1186.21	40,083.69	0.28	
	Gampaha	Gampaha	6322.14	6032.19	9643.75	251.42	1627.53	28652.46	0.26	0.31
		Negombo	4183.91	4119.28	4931.42	571.72	1210.49	18020.19	0.28	
		Nittambuwa	11938.91	10331.47	7487.24	236.41	752.02	36895.28	0.39	
	Kalutara	Kalutara	1592.704	1261.53	1071.06	0	44.70	4764.01	0.40	0.40
		Horana	1296.305	1044.43	708.40	266.65	15.31	3997.33	0.39	

The table 3.1 shows the calculation of vehicle factor for the motor cycles in western province. The calculation was done with the collected data from the manual survey.

The annual VKT factor for motor Cycles for Western Province can be obtained as, 0.31

Table 3.2: Annual VKT Calculation 2012

Province	District	Factor of Motor Cycles	Petrol Consumption by Vehicles in 2012	Average Consumption Rate	VKT(Km) For District	VKT for Province
Western Province	Colombo	0.21	274144107.6	55.09	3,166,298,052	8,156,531,342
	Gampaha	0.47	154277491.2	52.17	3,749,168,679	
	Kalutara	0.40	56683900.2	55.41	1,241,064,610	

The table 3.2 shows the annual VKT calculation for Motor Cycles.

Annual VKT for Motor Cycles = 8,156,531,342km

3.3 Sample Calculation with Fuel Growth

Table 3.3 Fuel Sale Data Collected from IOC and CEYPETCO

	DISTRICT WISE SALES					
	2010 (01.04.201031.04.2010)		2011		2012	
	PETROL	DIESEL	PETROL	DIESEL	PETROL	DIESEL
Colombo	112,642,200	141,018,900	169,982,466	257,316,476	184,807,107	249,223,425
Gampaha	73,293,014	128,831,011	111,927,809	219,337,800	123,871,491	226,426,389
Kalutara	24,763,200	43,335,600	38,029,200	76,074,900	41,556,900	74,589,944

Considering the base year as 2012 Growth Factor is calculated using 2010, 2011, 2012 Fuel sale data and predicted the Fuel sale Growth Factor for 2013 and 2014.

Table 3.4 Shows Calculated Fuel Growth Factor for Petrol

District	Fuel Sale Growth Factor				
	2010	2011	2012	2013	2014
Colombo	0.61	0.92	1.00	1.23	1.43
Gampaha	0.59	0.90	1.00	1.24	1.44
Kalutara	0.60	0.92	1.00	1.24	1.44

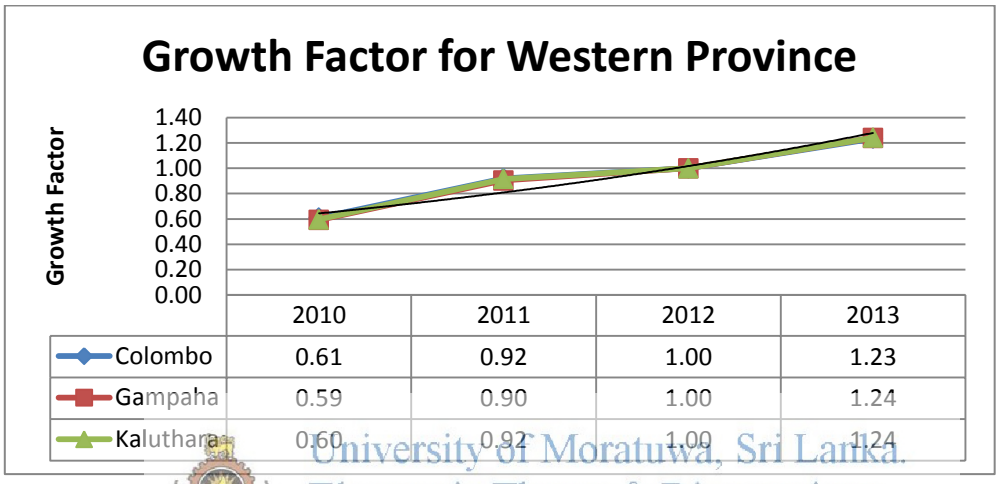

Figure 3.1: Predicted Fuel Growth Factor

The figure 3.1 depicts the annual fuel growth rate. With use of the predicted fuel growth factor the following sample calculation was done to obtain annual VKT for motor cycles. The calculation was done for the Western province. The figure 3.3 shows the predicted VKT for 2013 for the western province for motor cycles.

Table 3.5: Predicted VKT for the year 2013 for Motor Cycles

Province	District	VKT(Km) For District (Motor Cycles)	Fuel Growth Factor for 2013	VKT for 2013	VKT for Province
Western Province	Colombo	3,166,298,052.13	1.23	3,905,873,740	10,095,354,573
	Gampaha	3,749,168,679.08	1.24	4,649,188,632	
	Kalutara	1,241,064,610.73	1.24	1,540,292,201	

4. DATA COLLECTION AND ANALYSIS

4.1 Data Collection

The vehicles in Sri Lanka were classified as Motor Cycles, Three wheelers, Cars & S/Wagons, Pick Up, Jeep & Pajero, Passenger Van, Goods Van, Mini Bus, Bus, Light Truck, Medium Truck, Large Truck, 3 Axle Rigid Truck, 3 Axle Art'd Truck ., 4 Axle Art'd Truck., and Hand Tractor. Fuel Consumption Survey Forms were prepared specimen is attached in Annex I.

The data was collected by Road Development Authority planning division by distributing it to Executive Engineering divisions in all around the country. The survey forms were distributed and collected the fuel volume pumped for each type of vehicle from 6:00 am to 6:00pm in selected fuel stations in whole country. Collected Raw data is shown in Annex II.

The fuel sales data was collected from the Petroleum Corporation as well as from the IOC. The Data sheets are attached in the Annex III.

Figure 4.1: Data Collection

Figure 4.2: Data Collection

4.2 Analysis of Petrol Vehicles

The VKT was found for each vehicle and was added up the results to find the total vehicle Km travelled in Sri Lanka.

The figure 4.3 shows the VKT of petrol vehicles in Island wide. From that it's evident that motor cycles have the highest Vehicle Kilometers travelled within the petrol Vehicles. That is more than 15 billion kilometers. The second most highest is three wheelers and then the cars and wagons. It's clear that the motor cycle usage in Sri Lanka is higher than the other vehicle types. Figure 4.8 shows the breakdown of the VKT for motor cycles. It's well depicted that in Western Province and in North Western Province the motor cycle usage is higher than the other provinces.

Table 4.1: VKT for petrol vehicles in Province vise and Island wide in 2012

	VKT Calculation for Petrol Vehicles				
	Motor Cycles	**Three wheelers**	**Cars & S/Wagons**	**Jeep &Pajero**	**Passenger Van**
Island wide	**15,410,788,711.18**	**8,103,267,002.94**	**3,911,332,175.42**	**481,026,800.44**	**706,940,547.67**
Western Province	6,056,704,461.34	3463496057	2,236,086,618.75	270,380,246.54	376,268,941.38
Central Province	758,661,110.53	1078448961	319,250,445.68	21,327,274.12	62,137,728.85
Uwa Province	561,202,663.82	377618057.2	111,056,125.03	5,091,456.62	12,698,200.33
Sabaragamuwa Province	830,431,471.16	776057547	214,759,749.05	10,795,557.47	28,717,174.95
North Western Province	2,788,360,080.94	837440958.2	414,529,421.47	14,283,021.51	55,106,291.89
North Central Province	958,855,897.48	214071357.1	109,519,721.02	91,440,740.28	107,063,624.74
Northern Province	1,144,825,914.59	281785613.5	37,713,940.25	16,422,083.09	29,669,628.19
Eastern Province	624,114,907.68	431713488.6	132,887,782.65	20,008,779.98	24,521,126.73
Southern Province	1,687,632,203.64	642634963.4	335,528,371.53	31,277,640.84	10,757,830.6

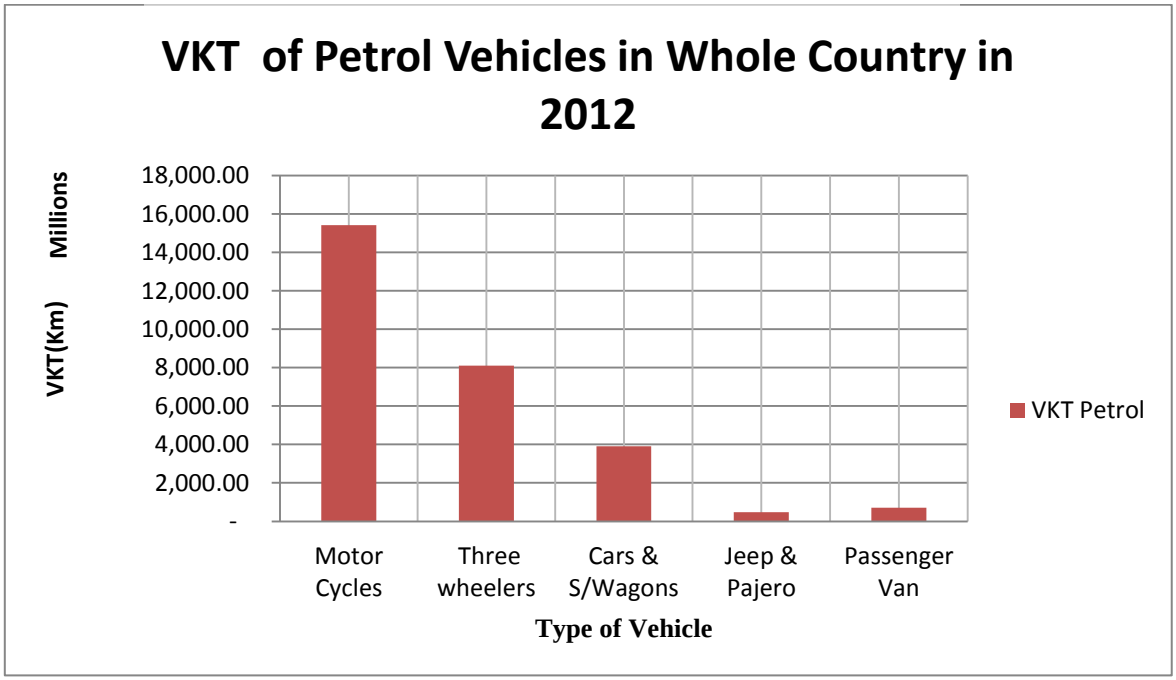

Figure 4.3: VKT of Petrol Vehicles in Whole Country

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Table 4.2: VKT for Diesel vehicles in Province vise and Island wide in 2012

	VKT for Diesel Vehicles				
	Three wheelers	**Cars & S/Wagons**	**Pick Ups**	**SUV**	**Passenger Van**
Island wide	1,664,253,619.54	505,192,062.38	515,785,961.44	466,700,992.30	1,546,734,865.44
Western Province	1,026,164,675.13	317,662,610.50	231,700,684.27	224,797,244.26	730,401,622.47
Central Province	46,885,662.84	18,931,256.76	29,006,786.35	41,043,564.24	190,216,743.58
Uwa Province	20,225,591.99	7,376,076.45	23,600,748.71	14,008,020.23	45,750,577.43
Sabaragamuwa Province	85,563,362.06	22,975,373.52	35,230,910.37	28,295,519.57	104,756,499.96
North Western Province	100,227,063.55	54,029,177.52	58,548,315.51	56,084,111.02	241,069,058.83
North Central Province	3,799,978.46	4,290,375.39	5,595,543.59	7,582,682.37	30,857,754.61
Northern Province	306,553,368.31	6,404,514.14	39,294,430.60	28,866,683.83	43,705,533.75
Eastern Province	20,413,212.76	47,829,862.10	141,311,683.46	39,613,848.82	112,277,393.09
Southern Province	54,420,704.43	51,134,617.62	53,489,128.15	58,403,473.68	156,539,861.34

Table 4.2: VKT for Diesel vehicles in Province vise and Island wide in 2012

	VKT for Diesel Vehicles				
	Goods Van	**Mini Bus**	**Bus**	**Light Truck**	**Medium Truck**
Island wide	585,506,327.19	249,863,338.68	647,050,561.39	1,284,608,549.67	1,403,304,873.1
Western Province	314,557,998.86	73,144,612.20	251,870,204.08	601,095,073.37	765,231,321.95
Central Province	49,685,957.20	46,427,704.52	126,938,623.37	111,864,074.23	208,198,204.57
Uwa Province	17,633,273.28	7,725,964.40	35,584,112.56	39,256,992.50	37,393,903.40
Sabaragamuwa Province	32,114,640.06	23,957,518.94	48,982,673.51	94,032,748.23	117,124,572.57
North Western Province	55,967,005.05	44,923,113.03	68,462,760.80	170,128,018.55	184,653,287.55
North Central Province	6,508,866.08	3,989,094.46	10,368,329.16	26,068,449.41	20,753,999.94
Northern Province	30,259,960.81	14,162,420.06	83,288,156.53	70,795,474.85	47,924,360.43
Eastern Province	45,179,325.36	30,934,614.85	125,202,919.70	106,950,603.71	60,953,070.77
Southern Province	71,034,750.09	27,063,982.30	63,565,468.68	132,419,743.32	119,081,220.75

Table 4.2: VKT for Diesel vehicles in Province vise and Island wide in 2012

	VKT for Diesel Vehicles			
	Large Truck	**3 Axel Rigid Tk**	**4 Axel Rigid Tk**	**Tractors**
Island wide	1,117,990,771.08	60,176,013.27	208,010,853	125,666,475
Western Province	558,242,017.21	57,902,775.25	174,198,114.73	61,454,285.11
Central Province	109,922,946.31	1,795,280.12	8,584,170.40	12,855,221.45
Uwa Province	40,089,525.47	4,093,162.58	1,726,388.87	4,358,713.44
Sabaragamuwa Province	49,223,856.97	6,271,306.99	3,251,590.83	7,789,236.49
North Western Province	171,136,469.89	6,168,773.69	8,583,313.39	15,278,128.98
North Central Province	21,725,274.47	842,828.90	811,999.62	2,497,898.44
Northern Province	168,585,448.27	9,595,418.90	18,779,416.48	6,937,471.57
Eastern Province	148,305,356.85	39,196,305.78	8,626,677.75	10,162,344.87
Southern Province	97,889,148.89	4,199,343.30	6,529,778.18	10,033,478.04

Note:

- The above figures don't include the VKT of Ceylon Transport Board buses and Private buses. The data can be collected directly from CTB and corresponding private bus companies and can calculate the VKT separately.
- The heavy vehicles like containers were not considered because the data for them should be collected from the container yards.
- The fuel usage factor was calculated by only considering the fuel stations since others fuel usage factors can be directly calculated from the directly available data.Ex: For CTB buses number of buses and the fuel consumption is readily available in CTB.

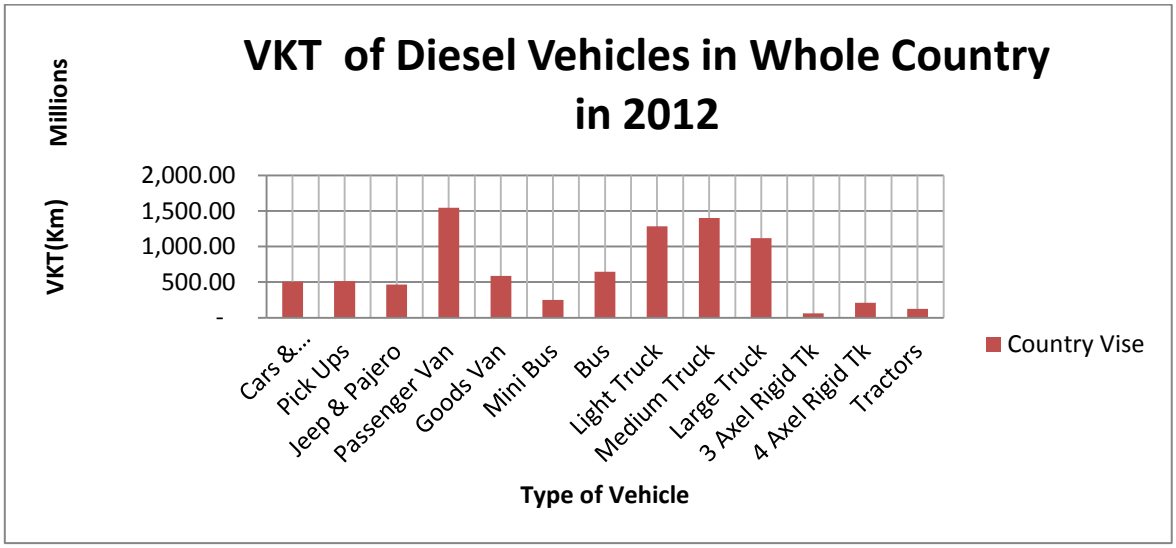

Figure 4.4: VKT of Diesel Vehicle in Whole Country

The figure 4.3 depicts the VKT of all the petrol vehicles in whole country. The figure 4.4 depicts the VKT of diesel vehicles where the passenger van shows the highest VKT out of all the diesel vehicle types.

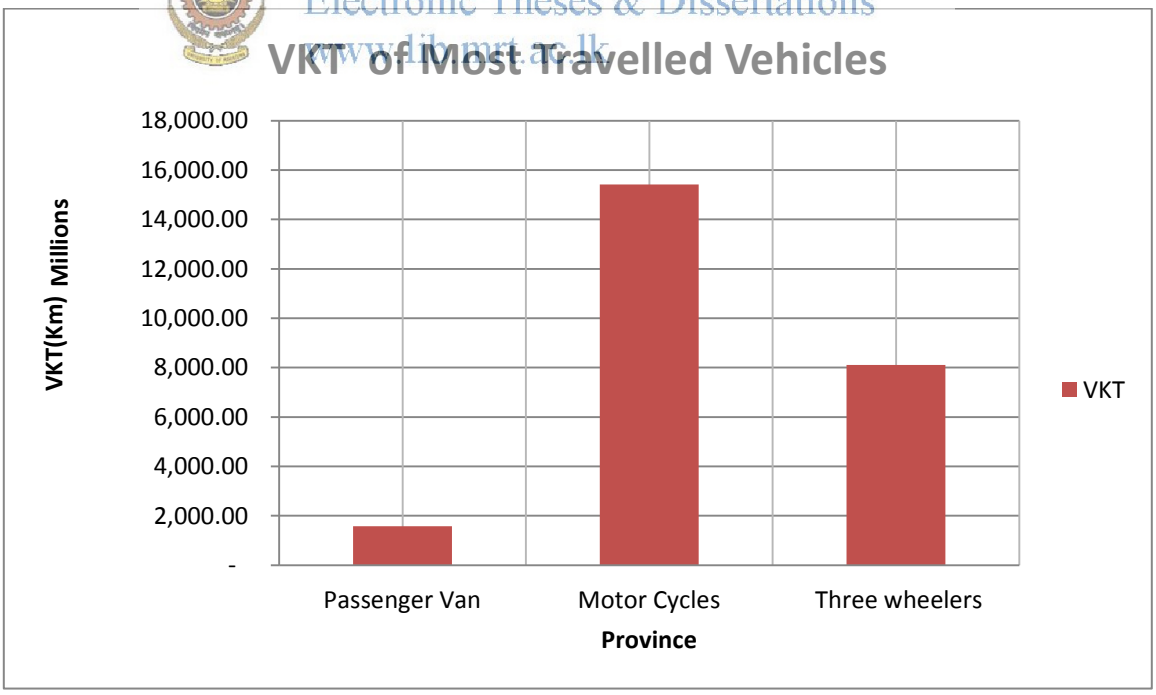

Figure 4.5:VKT of Most Travelled Vehicles

Figure 4.5 shows the chosen highest Vehicle Kilometers Travelled vehicles including diesel and petrol vehicles. It's evident that the motor cycles has the highest vehicle kilometers travelled in Sri Lanka.

Table 4.1 New Registration (2002 - 2010) From Department of Motor Traffic

CLASS OF VEHICLE	2002	2003	2004	2005	2006	2007	2008	2009	2010
Motor cars	12,003	21,184	19,116	17,283	27,578	22,603	20,237	5,762	23,072
Motor Tricycle	20,876	36,204	43,789	41,085	64,466	43,068	44,804	37,364	85,648
Motor Cycles	54,762	86,877	124,474	130,696	156,626	182,508	155,952	135,421	204,811
Buses	1,429	1,949	2,167	2,069	3,346	2,637	1,180	739	2,491
Dual purpose vehicles	8,591	13,268	10,736	6,851	7,245	5,193	2,856	1,280	11,712
Lorries	8,166	11,158	10,703	14,262	20,436	18,408	14,038	8,225	11,845
Land vehicles-Tractors	7,078	10,004	11,535	15,597	19,040	21,346	24,357	13,951	17,363
Land vehicles-Trailers	446	858	1,322	1,826	1,785	2,129	1,775	1,333	2,301
TOTAL	113,351	181,502	223,842	229,669	300,522	297,892	265,199	204,075	359,243

Table 4.2:Predicted Vehicle Population for the year 2012

CLASS OF VEHICLE	2012
Motor cars	452444
Three wheelers	639919
Motor Cycles	2433597
Buses	88774
Dual purpose vehicles	221862
Lorries	327311
Land vehicles-Tractors	315536
Land vehicles-Trailers	50303
TOTAL	4529745

The table 4.2 shows the number of vehicles in the year 2012. With respect to that the figure 4.6 shows the VKT per vehicle when considered the whole country. From that it's evident that the most used vehicle in the country is three wheelers where the second most used vehicle is motor cycles.

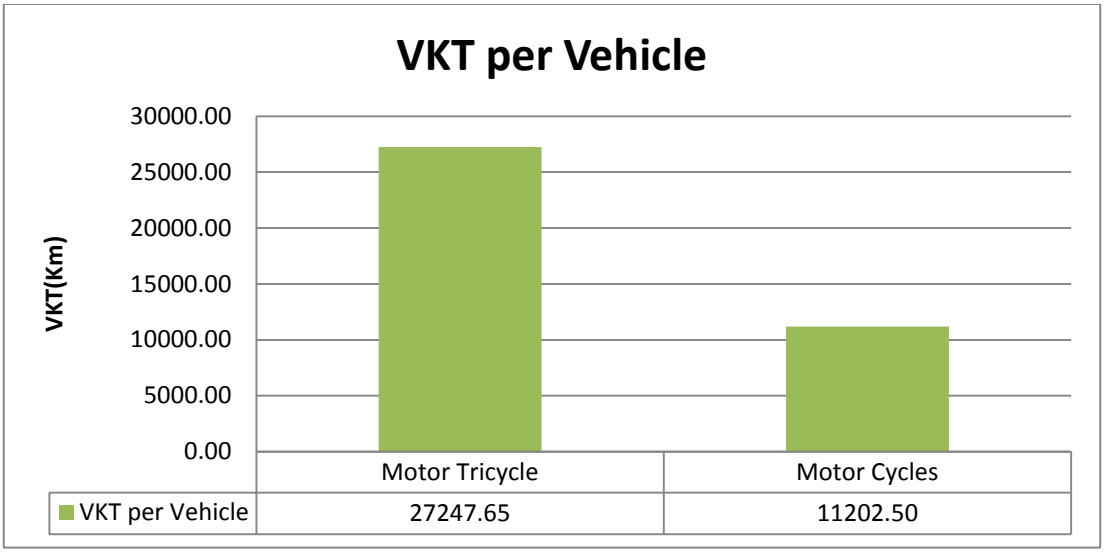

Figure 4.6: VKT per Vehicle

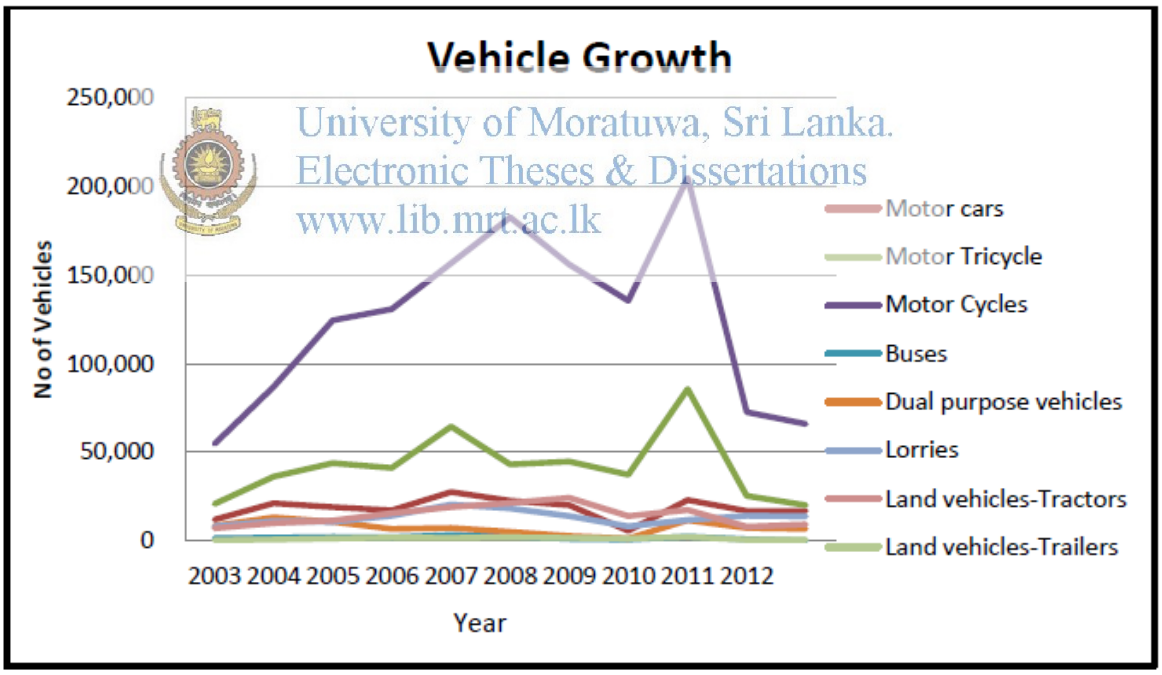

Figure 4.7: Vehicle Growth

The figure 4.8 shows the VKT for motor cycles in province wise. It was proven from the figure 4.6 the motor cycles are the second most used vehicle in Sri Lanka. From the provincial breakdown of the VKT for motor cycles it's clear that there's higher usage in western province and the second highest is North Western province.

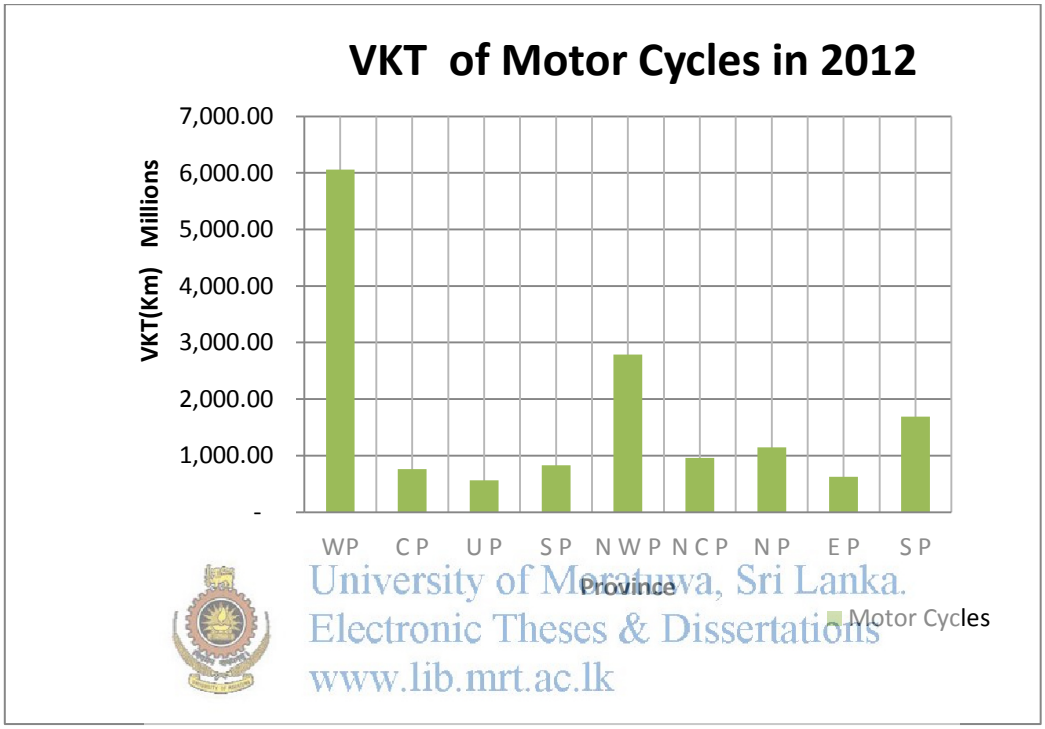

Figure 4.8 : VKT of Motor Cycles

The figure 4.9 shows the VKT for in province wise. It was proven from the figure 4.6 the three wheelers are the most used vehicle in Sri Lanka. From the provincial breakdown of the VKT for Three wheelers, it's clear that there's higher usage in western province and the second highest is North Western Province.

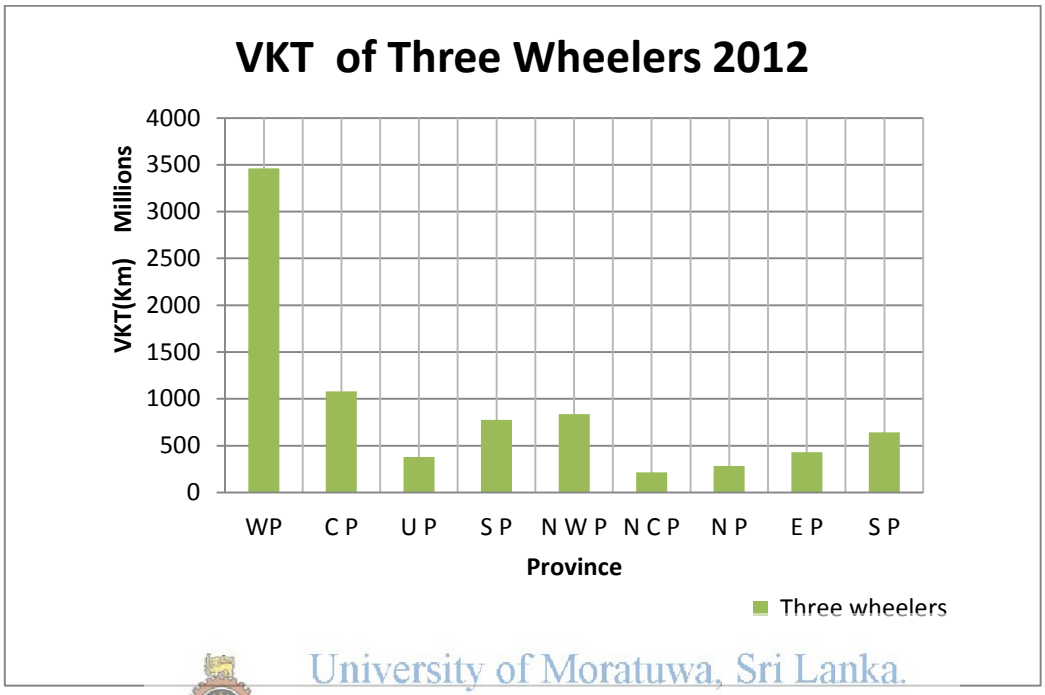

Figure 4.9: VKT for three wheelers

The figure 4.10 shows the VKT analysis for the cars and wagons. The highest usage is in western province. And that is comparatively higher by 5 billion kilometers than all the other provinces. The second highest is north western province.

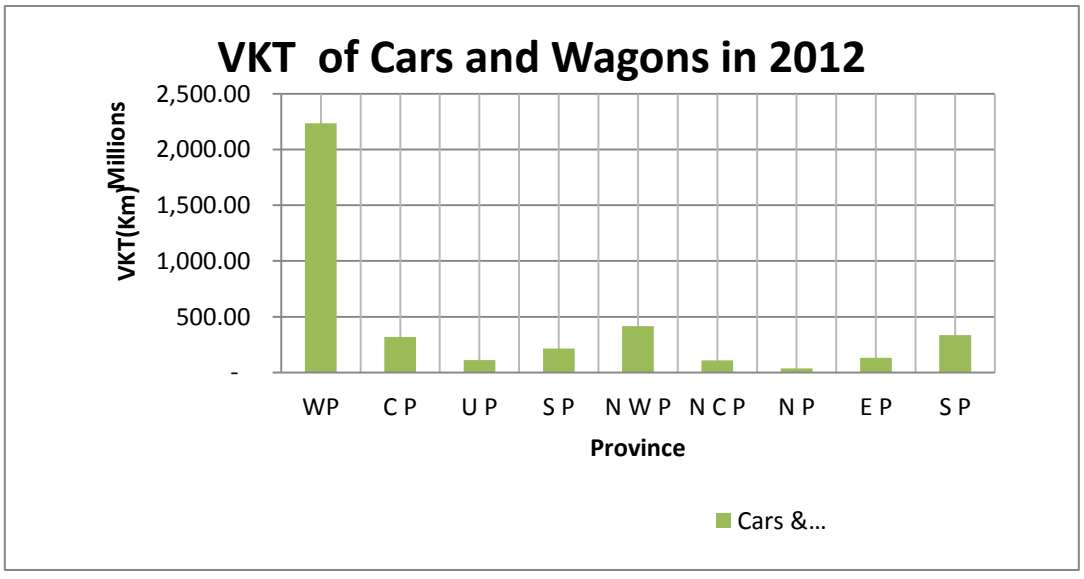

Figure 4.10: VKT of cars and Wagons

The figure 4.11 shows the VKT analysis for the SUV. When considered the geographical distribution the usage of this vehicle type is different than the usage of other vehicle types. For this vehicular category the vehicle usage is almost same in Western and North Central Province. It is nearly 9.5 billion kilometers. The minimum usage is in Uva Province.

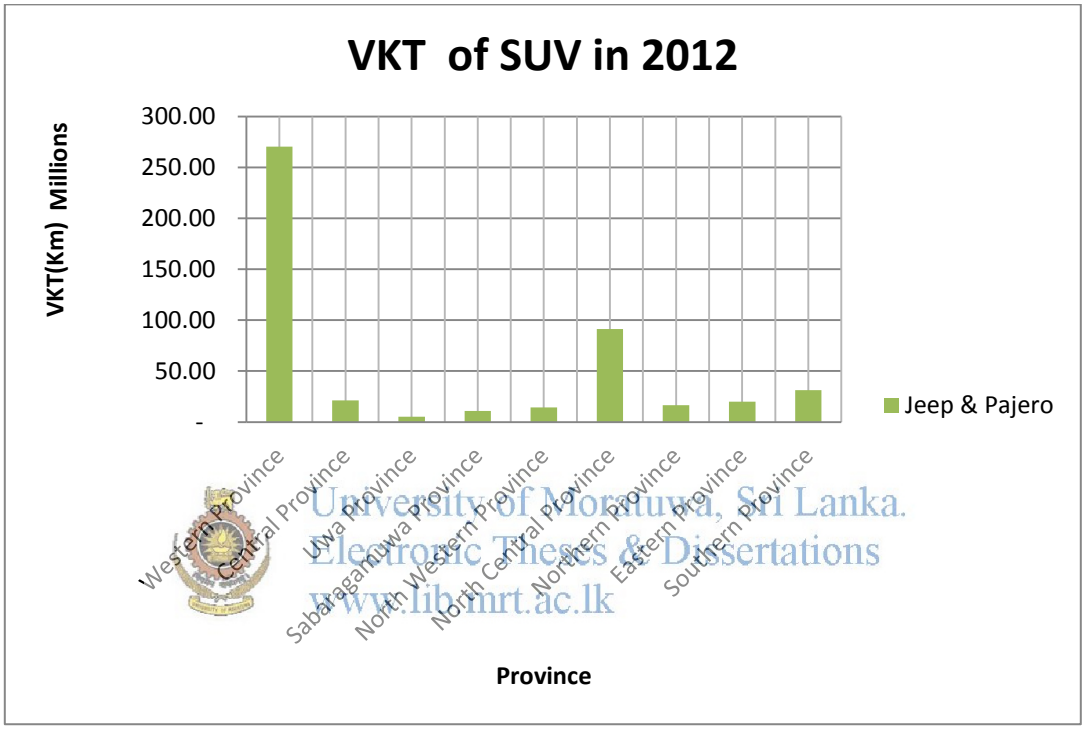

Figure 4.11: VKT of SUV

VKT analysis for the passenger vans is shown in the figure 4.8 shows the VKT analysis for the passenger vans. When considered the geographical distribution the usage of this vehicle type is far more same as Jeeps and Pajeros. The maximum usage is in Western Province and the second highest usage is in North Central Province. In other provinces the usage is far below than those two.

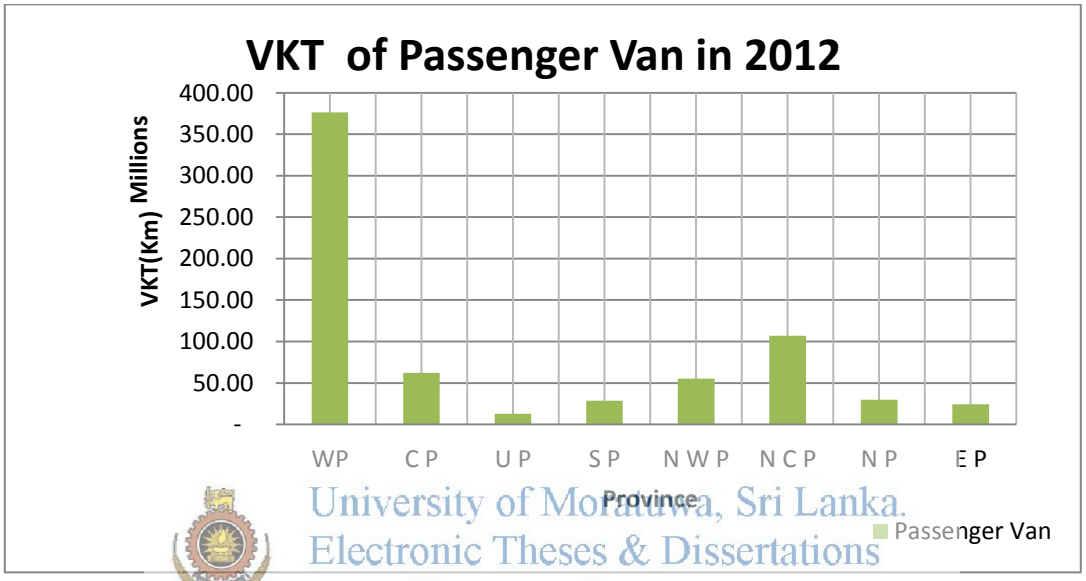

Figure 4.1: VKT of Passenger Vans

4.3 Analysis of Diesel Vehicles

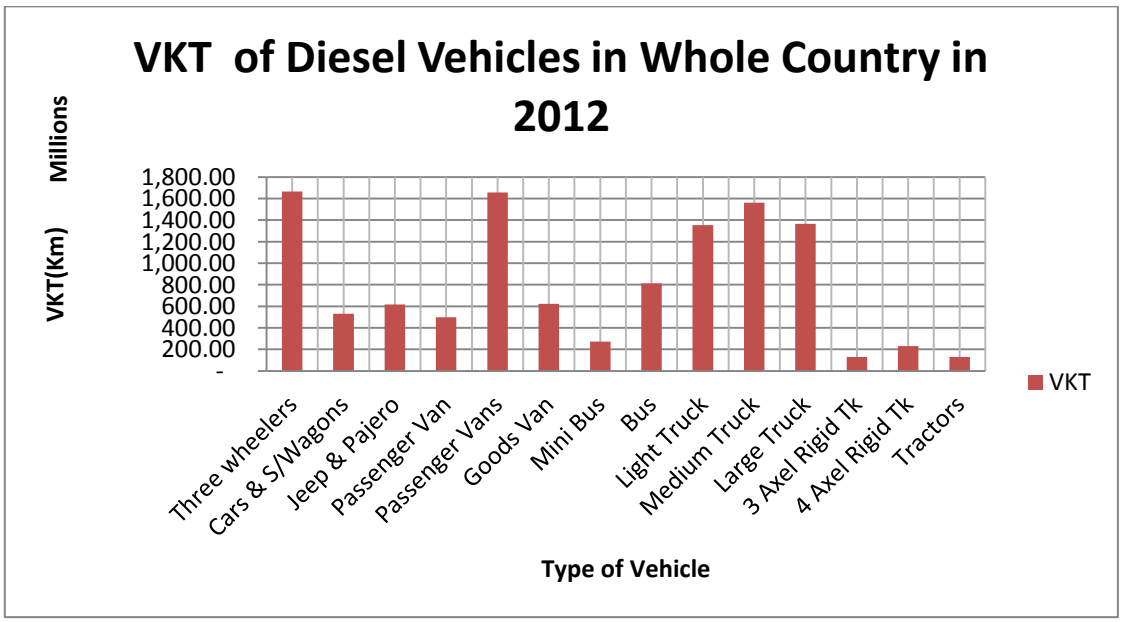

Figure 4.2:VKT of Diesel Vehicles in Whole Country

The table 4.3 shows the VKT values for the different vehicles.

Table 4.2: VKT for Diesel Vehicles in 2012

	Three wheelers	Cars & S/Wagons	Pick Ups	SUV
Country Vise	**1,664,253,619.54**	**530,633,863.99**	**617,778,231.00**	**498,695,148.02**
Western Province	1,026,164,675.13	317,662,610.50	231,700,684.27	224,797,244.26
Central Province	46,885,662.84	18,931,256.76	29,006,786.35	41,043,564.24
Uwa Province	20,225,591.99	7,376,076.45	23,600,748.71	14,008,020.23
Sabaragamuwa Province	85,563,362.06	22,975,373.52	35,230,910.37	28,295,519.57
North Western Province	100,227,063.55	54,029,177.52	58,548,315.51	56,084,111.02
North Central Province	3,799,978.46	4,290,375.39	5,595,543.59	7,582,682.37
Northern Province	306,553,368.31	6,404,514.14	39,294,430.60	28,866,683.83
Eastern Province	20,413,212.76	47,829,862.10	141,311,683.46	39,613,848.82
Southern Province	54,420,704.43	51,134,617.62	53,489,128.15	58,403,473.68

Table 4.3: VKT for Diesel Vehicles in 2012

	Passenger Van	Goods Van	Mini Bus	Bus	Light Truck
Country Vise	1,655,575,045.06	622,941,776.81	272,329,024.76	814,263,248.38	1,352,611,178.17
Western Province	730,401,622.47	314,557,998.86	73,144,612.20	251,870,204.08	601,095,073.37
Central Province	190,216,743.58	49,685,957.20	46,427,704.52	126,938,623.37	111,864,074.23
Uwa Province	45,750,577.43	17,633,273.28	7,725,964.40	35,584,112.56	39,256,992.50
Sabaragamuwa Province	104,756,499.96	32,114,640.06	23,957,518.94	48,982,673.51	94,032,748.23
North Western Province	241,069,058.83	55,967,005.05	44,923,113.03	68,462,760.80	170,128,018.55
North Central Province	30,857,754.61	6,508,866.08	3,989,094.46	10,368,329.16	26,068,449.41
Northern Province	43,705,533.75	30,259,960.81	14,162,420.06	83,288,156.53	70,795,474.85
Eastern Province	112,277,393.09	45,179,325.36	30,934,614.85	125,202,919.70	106,950,603.71
Southern Province	156,539,861.34	71,034,750.09	27,063,982.30	63,565,468.68	132,419,743.32

Table 4.4 : VKT for Diesel Vehicles in 2012

	Medium Truck	Large Truck	3 Axel Rigid Tk	4 Axel Rigid Tk	Tractors
Country Vise	1,561,313,941.92	1,365,120,044.33	130,065,195.52	231,091,450.25	131,366,778.39
Western Province	765,231,321.95	558,242,017.21	57,902,775.25	174,198,114.73	61,454,285.11
Central Province	208,198,204.57	109,922,946.31	1,795,280.12	8,584,170.40	12,855,221.45
Uwa Province	37,393,903.40	40,089,525.47	4,093,162.58	1,726,388.87	4,358,713.44
Sabaragamuwa Province	117,124,572.57	49,223,856.97	6,271,306.99	3,251,590.83	7,789,236.49
North Western Province	184,653,287.55	171,136,469.89	6,168,773.69	8,583,313.39	15,278,128.98
North Central Province	20,753,999.94	21,725,274.47	842,828.90	811,999.62	2,497,898.44
Northern Province	47,924,360.43	168,585,448.27	9,595,418.90	18,779,416.48	6,937,471.57
Eastern Province	60,953,070.77	148,305,356.85	39,196,305.78	8,626,677.75	10,162,344.87
Southern Province	119,081,220.75	97,889,148.89	4,199,343.30	6,529,778.18	10,033,478.04

VKT analysis for the diesel vehicles are shown in the figure 4.13 shows the VKT analysis for the passenger vans. The road usage of Three Wheelers and passenger vans are almost same in the country. The second most important vehicles to be considered are trucks.

The figure 4.14 shows the VKT for Three Wheelers with respect to different provinces. From that it's evident that the highest usage is in the Western Province. The second highest is in the Northern Province.

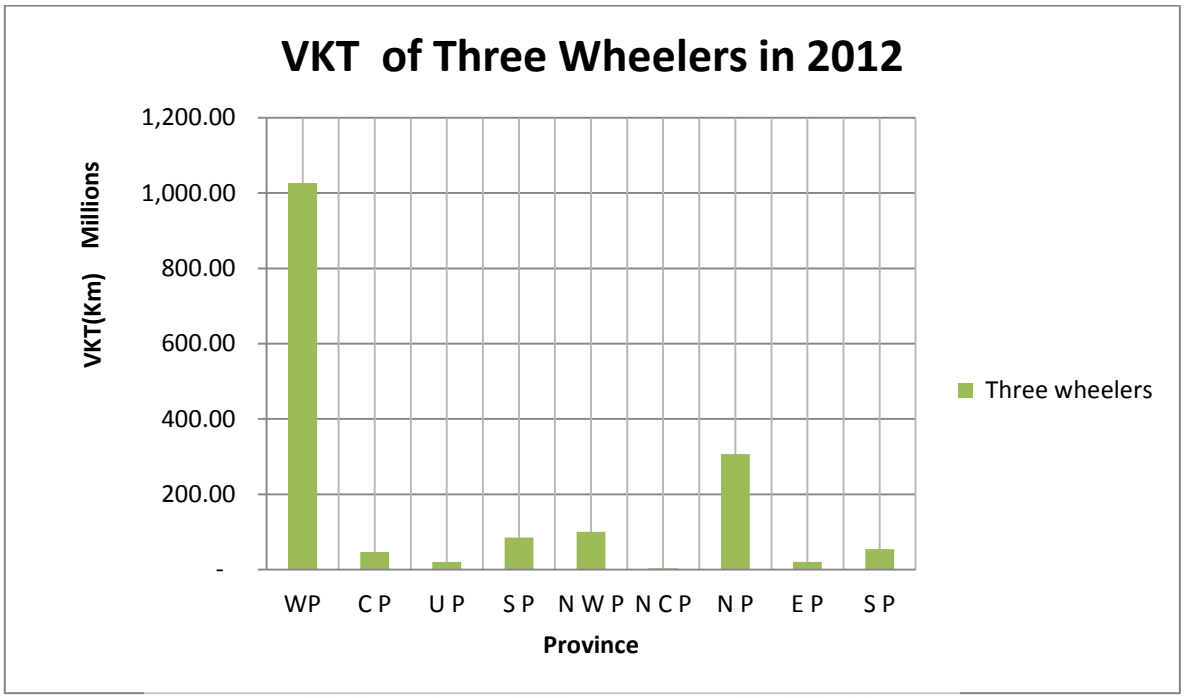

Figure 4.3: VKT of Three Wheelers

The figure 4.15 shows the VKT for Pick Ups with respect to different provinces. From that it's evident that the highest usage is in the Western Province. The second highest is in the Eastern Province. In Eastern, Southern and in North Western the usage is almost same.

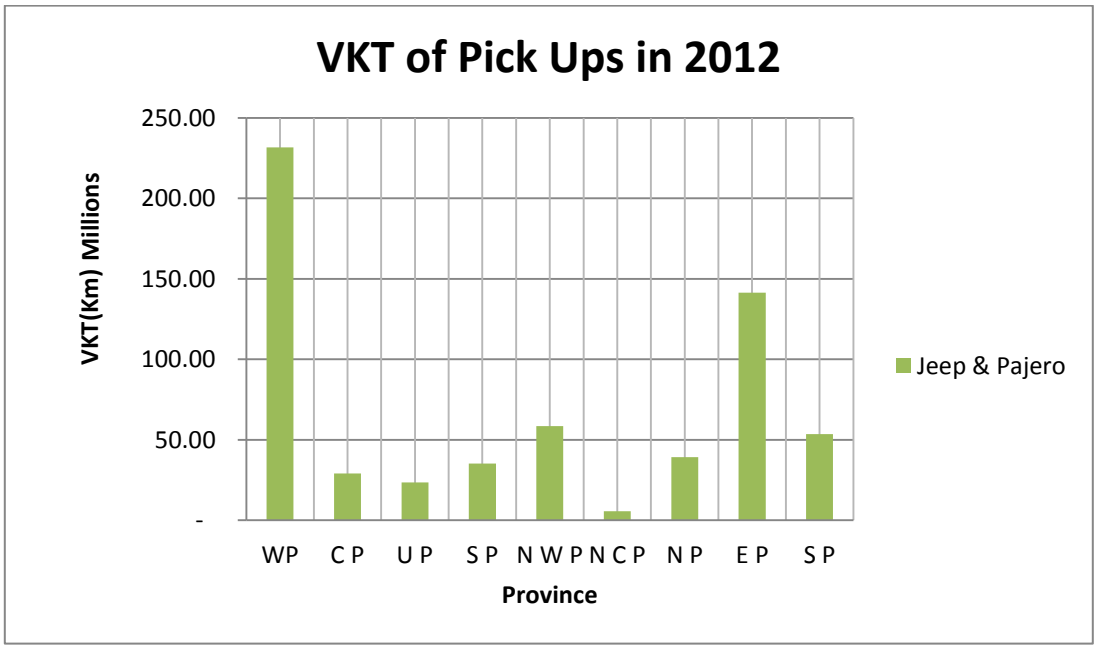

Figure 4.4: VKT of Pick Ups

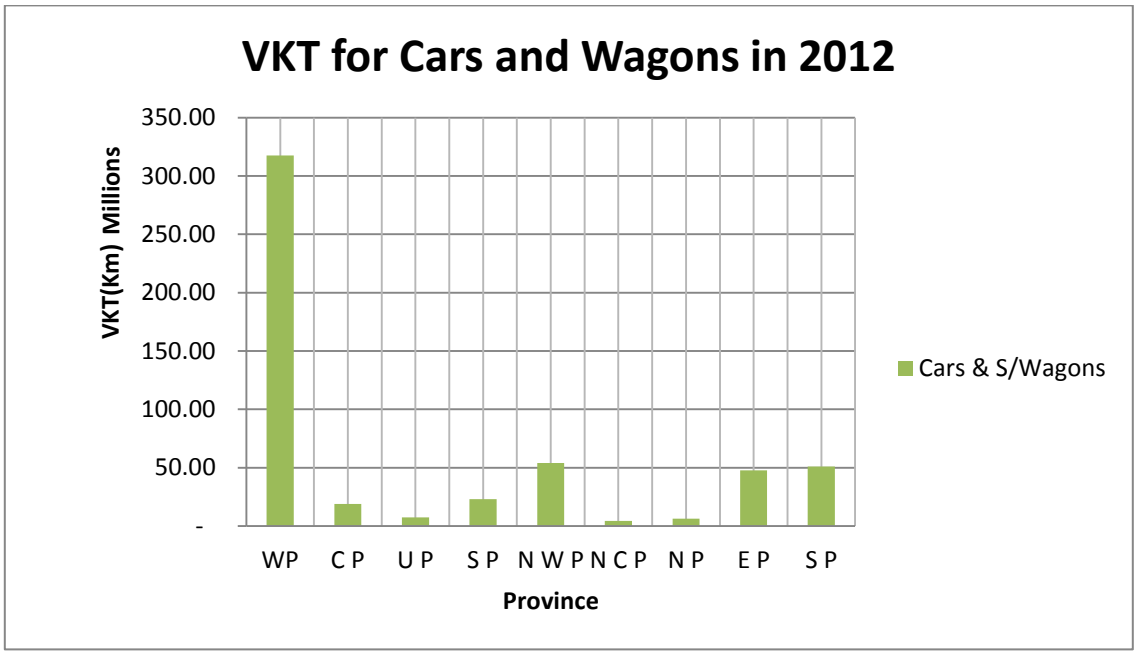

Figure 4.5: VKT for cars and wagons

The figure 4.17 shows the VKT for SUV with respect to different provinces. From that it's evident that the highest usage is in the Western Province. The second highest is in the North Western Province.

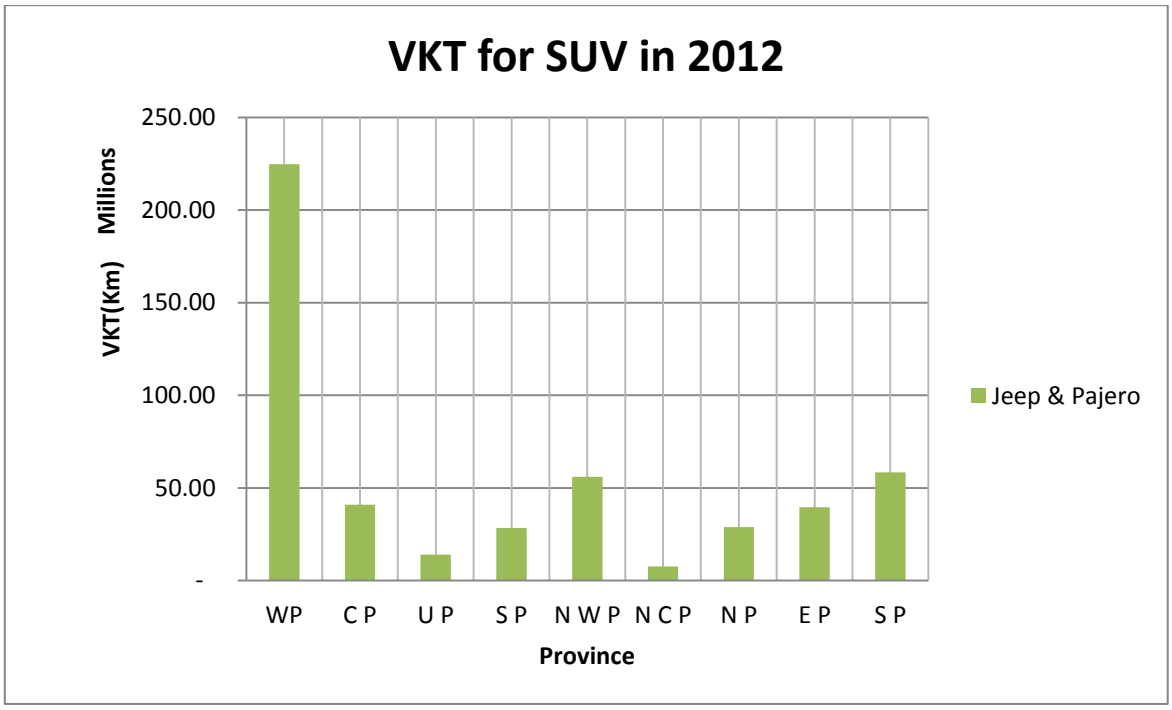

Figure 4.6: VKT for Jeeps and Pajeros

The figure 4.18 shows the VKT for passenger vans with respect to different provinces. From that it's evident that the highest usage is in the Western Province. In Southern and in North Western the usage is almost same.

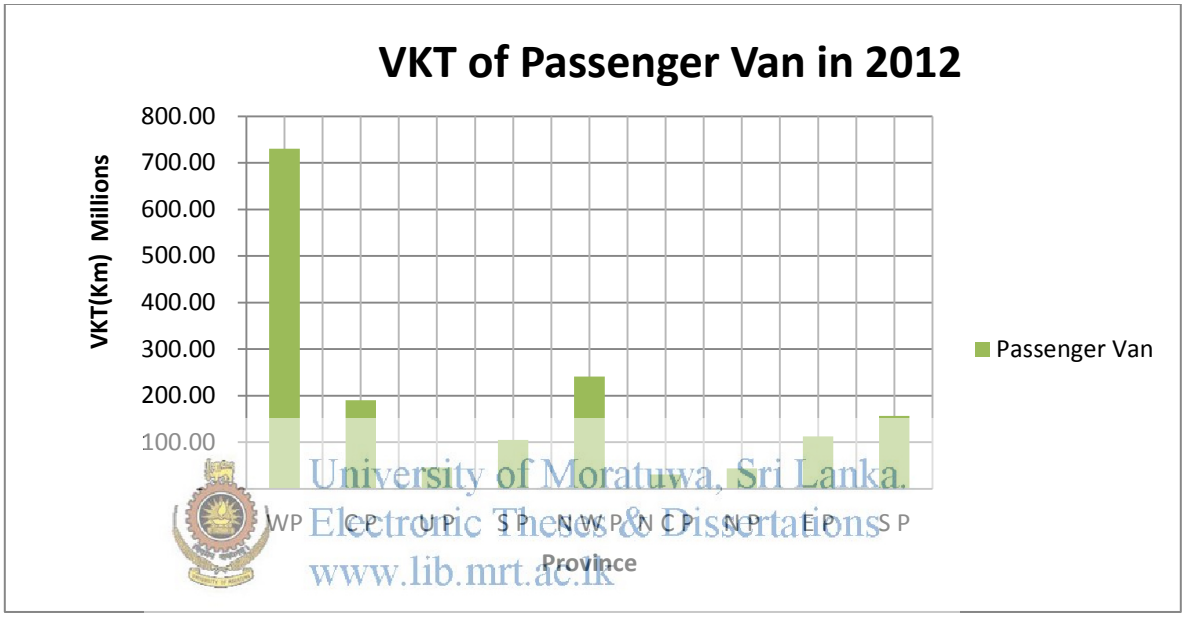

Figure 4.7: VKT of Passenger Van

The figure 4.19 shows the VKT for Mini Bus with respect to different provinces. From that it's evident that the highest usage is in the Western Province. In Central and in North Western the usage is almost same.

The figure 4.19 shows the VKT for Buses with respect to different provinces. From that it's evident that the highest usage is in the Western Province. In Central and in Eastern the usage is almost same.

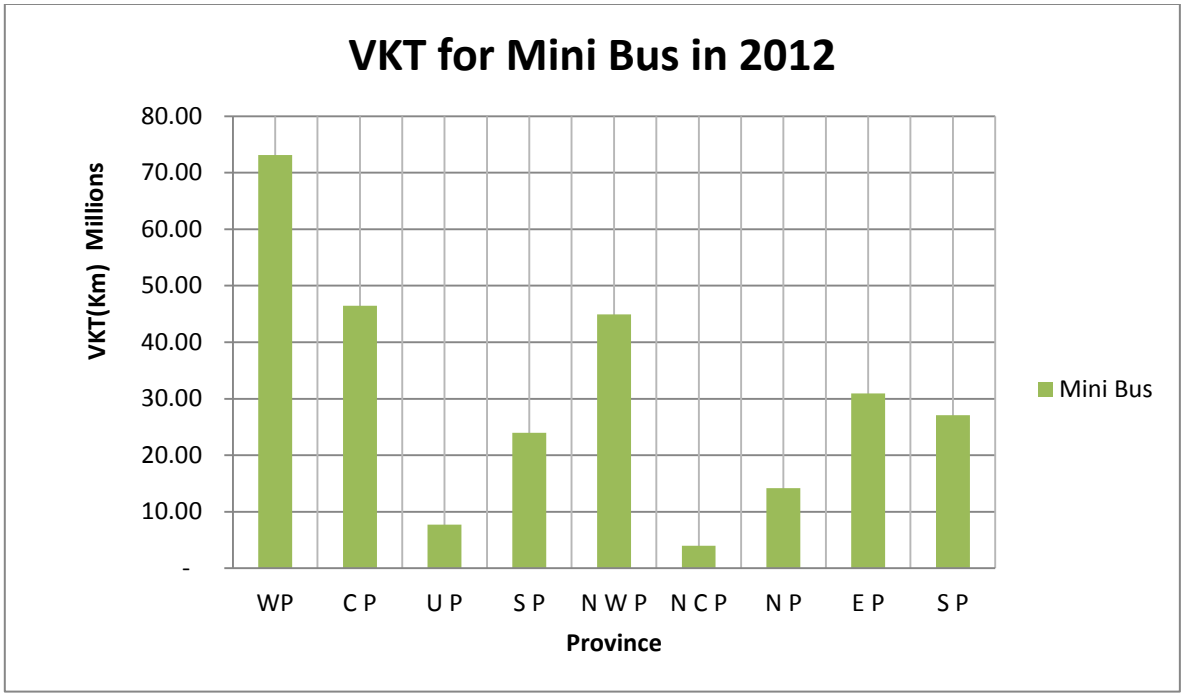

Figure 4.8 : VKT for Mini Bus

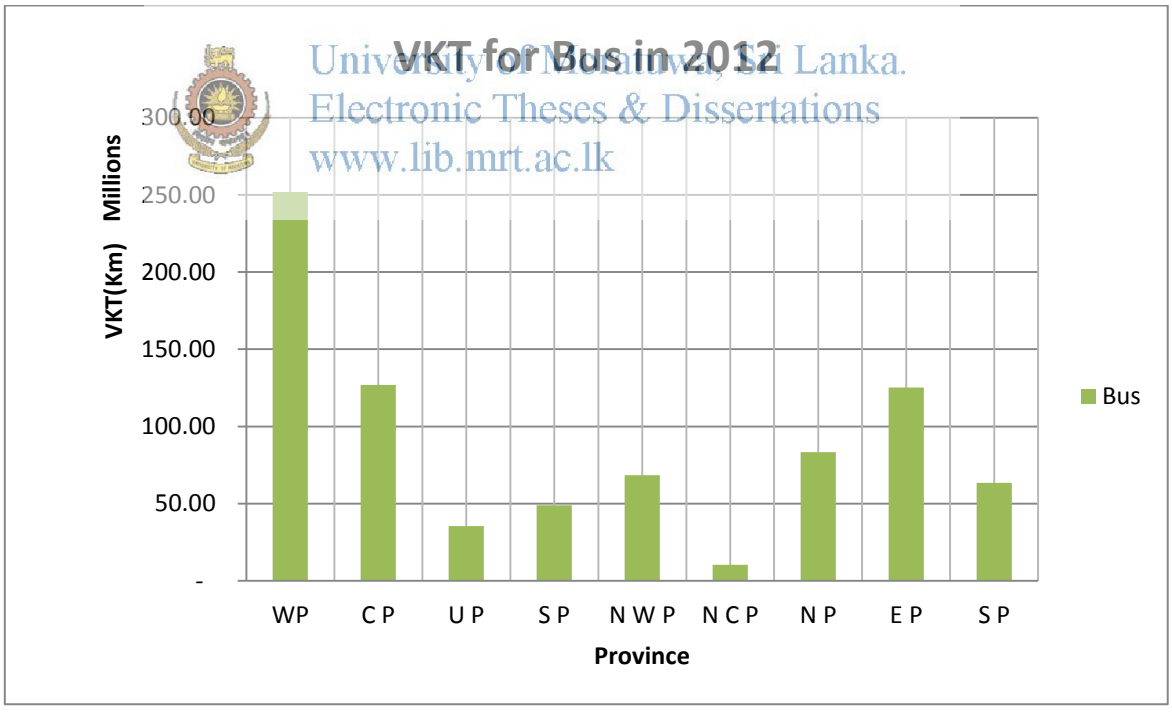

Figure 4.9: VKT for Bus

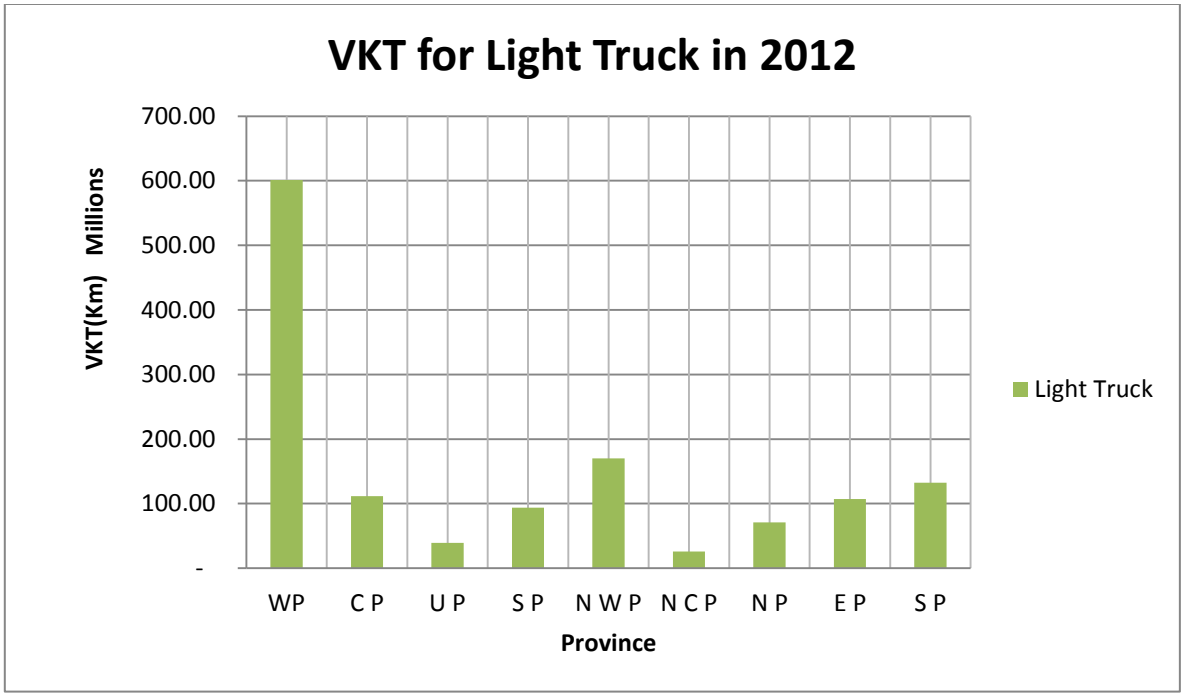

Figure 4.10: VKT for Light Truck

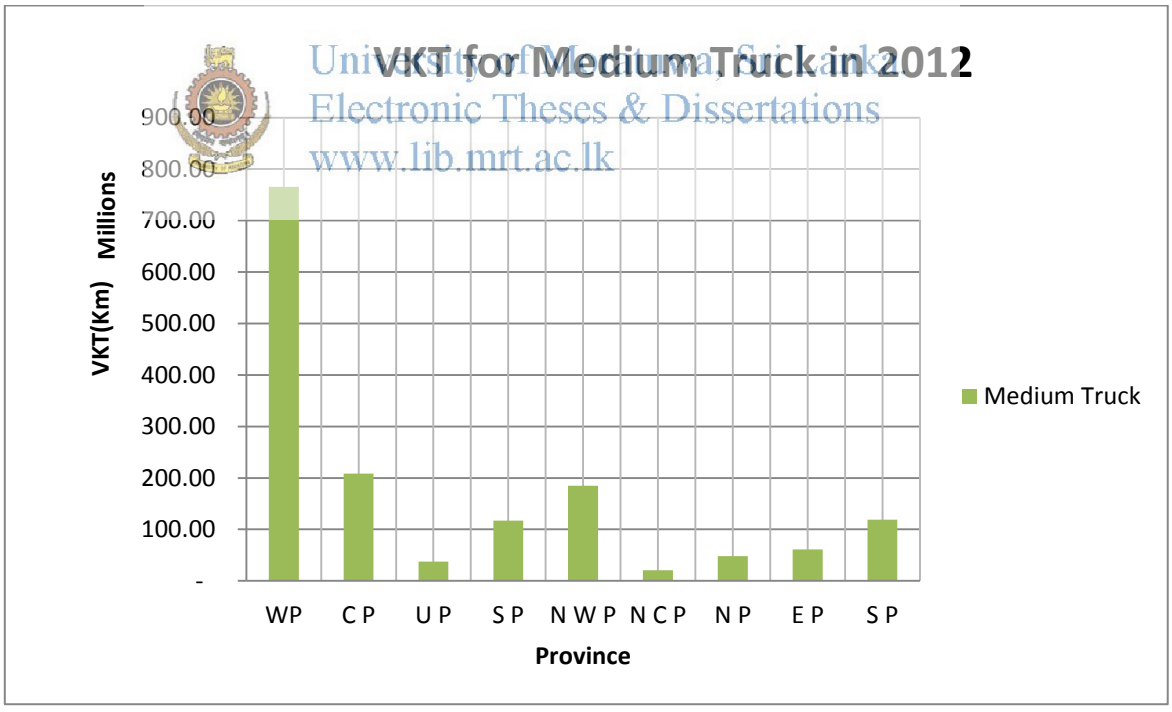

Figure 4.11: VKT for Medium Truck

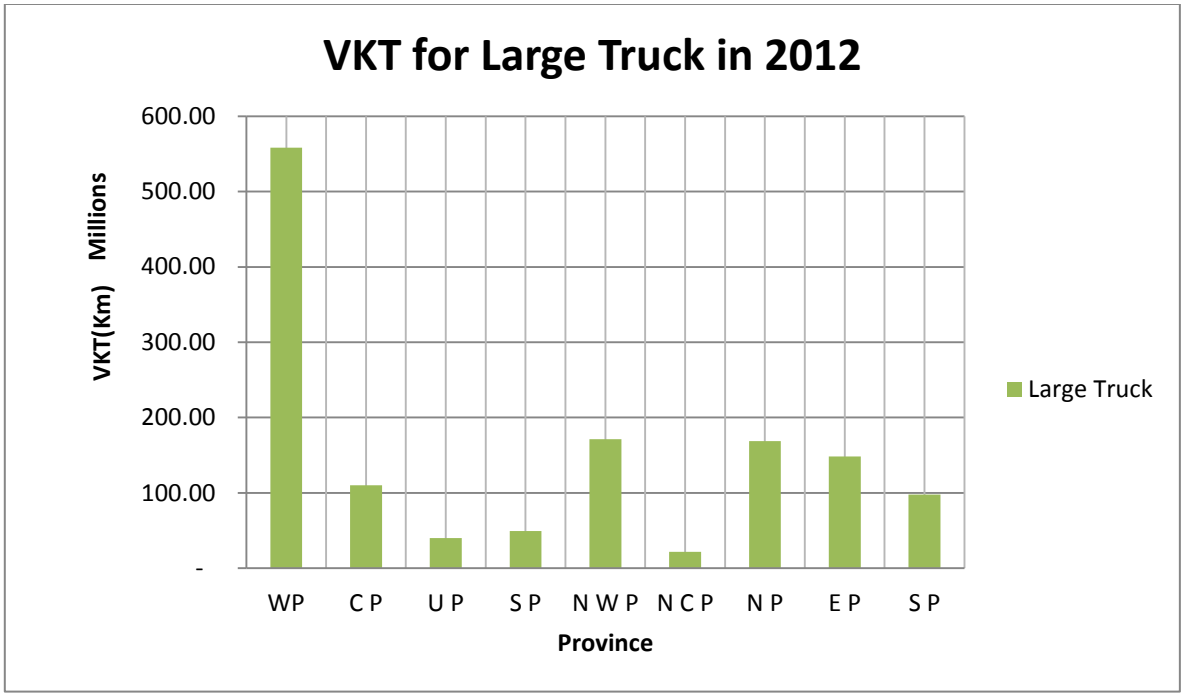

Figure 4.12: VKT for Large Truck

5. DEVELOPMENT OF METHODOLOGY TO FIND THE FUTURE VKT

The sample study was done for the motor cycles for the Colombo District. The collected data from all 30 stations were used for this calculation. With the collected data factor of motor cycle was calculated for each station. The distribution of data was analyzed through hypothesis testing to find the number of stations that should be selected under the probability of 95%. The same procedure should be followed for each district and each vehicular type. After finding the possible number of stations for each district to calculate the each vehicular proportion the calculation of VKT for future years can be performed by collecting data from those selected sample stations.

5.1 The Sample Calculation Performed for Colombo District for Motor Cycles

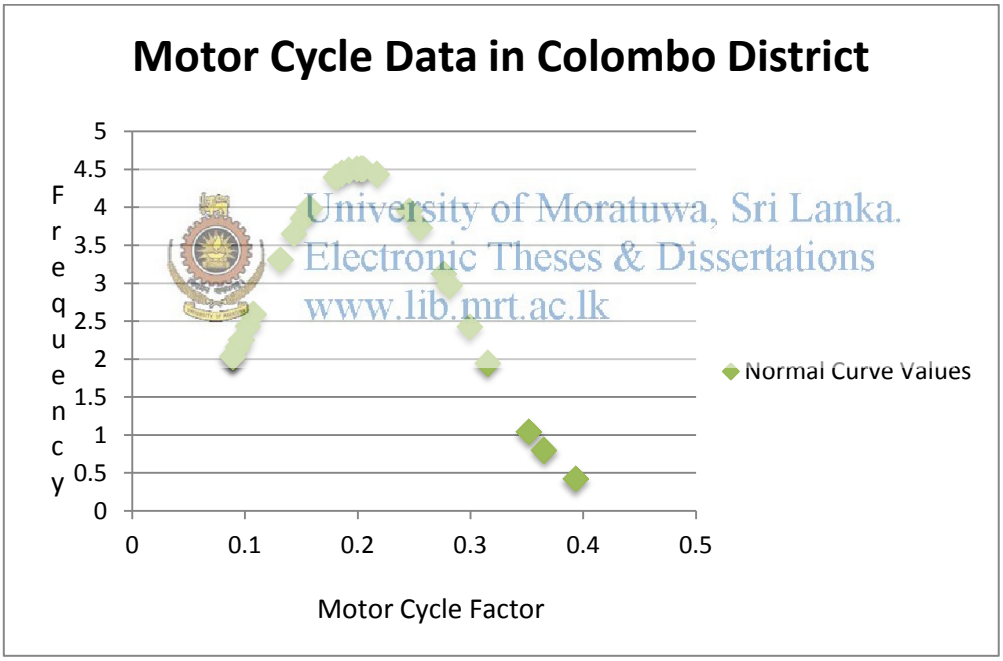

Figure 5.1: Motor Cycle factor distribution

The figure 5.1 shows the density distribution of the collected data. It reveals that the data is normally distributed.

5.1.1 Accuracy of the Selected Sample Stations in Colombo District with Use of Central Limit Theorem

Mean of the Population (m) = 0.21

Standard Deviation of the Population (s) = 0.088

If 8 samples stations are selected randomly the probable region for the means for them to be under 95% probability region is

= Mean ± Probability Factor x Standard Dev. / (Sample Size) ^0.5

$$= 0.21 \mp 1.96 \times 0.0885/\sqrt{8}$$

= 0.15 to 0.27

5.1.2 Testing the Sample with Hypothesis Testing

Selected following hypotheses where m_1 represents the mean of the population and m_2 represents the mean of the sample.

Null Hypothesis: $H_0 = m_1 = m_2 = 0.21$

Other Hypothesis: $H_1 = m_2 \neq 0.21$

Sample mean which lies closer to sample mean would be considered as evidence in favor of null hypotheses. On the other hand, sample mean that is considerably less than or more than the population mean would be evidence inconsistent with null hypotheses, therefore favoring H_1.

Mean of the population (m) = 0.21

Standard Deviation of the population (s) = 0.088

Selected Sample size is (n) = 5

Sample standard deviation = $0.088/\sqrt{5}$

= 0.039

The probability of committing a type I error is

$$\alpha = P(m_2 > 0.19 \text{ when } m_1 = 0.21) + P(m_2 < 0.23 \text{ when } m_1 = 0.21)$$

The Z values corresponding to $m_{2'} = 0.19$ and $m_{2''} = 0.23$ when H_0 is true.

$$Z_1 = \frac{0.19 - 0.21}{0.039} = -0.5128 \qquad Z_1 = \frac{0.23 - 0.21}{0.039} = 0.5128$$

Therefore,

$$\alpha = P(Z > -0.5128) + P(Z < 0.5128) = 2P(Z > -0.5128)$$

= 0.3050x2

= 0.61

Thus 6% of all samples of size 5 would lead us to reject $m_1=m_2=0.21$ when in fact it is true. To reduce α, we have a choice of increasing the sample size or widening the fail to reject region. Suppose that we increase the sample size to 8.

Then

Sample standard deviation = $0.088/\sqrt{8}$

= 0.0311

$Z_1 = \frac{0.19-0.21}{0.0311} = -0.642$ $Z_1 = \frac{0.23-0.21}{0.0311} = 0.642$

$\alpha = P(Z> -0.642) + P(Z <0.642) = 2P(Z> -0.642)$

= 0.2611 x 2

= 0.522

Thus 5% of all samples of size 8 would lead us to reject $m_1=m_2=0.21$

Hence 8 stations can be selected randomly to obtain the motor cycle proportion in Colombo District with 95% probability.

Total Population - Total No of station

Sample - Minimum No of stations that can represent by the total No of Station

In the case of determination of Motor cycle factor for Colombo District, only 8 station can be randomly selected and can find the Motor cycle factor.

Similarly other vehicle types also can be tested by hypothetically and can be found the minimum no of stations that can represent the entire fuel stations.

5.2 Analysis with Randomly Selected Station

5.2.1 Analysis with Randomly Selected 8 Station

Table 5.1: Randomly Selected 8 Stations

Islandwide Fuel Consumption Survey			Petrol						Motor Cyles			
			Motor Cycles	Three wheelers	Cars & S/Wagons	Jeep & Pajero	Passenger Van	Total Petrol Consumption	Using one Sample	Average	Standard Dev	Stdv/(n)^0.5
Province	District	Filling station	Liters	Liters	Liters	Liters	Liters					
Western Province	Colombo	910, Lanka Filling Station, Ranala	1002.24	1396.106	1786.092	72.439	93.67	4350.5465	0.191975786	0.20	0.051	0.031
Western Province	Colombo	R.C.Wikramarachchi, No.107, Avissawella Rd., Kaduwela	322.785	563.34	302.118	47.19	93.909	1329.342	0.212346349			
Western Province	Colombo	No.131, Bekariya junction, Attidiya	385.928	540.64	1217.99	437.23	555.33	3137.118	0.102516599			
Western Province	Colombo	No.133, New Galle Rd., Moratuwa	251.66	234.6	633.86		8.57	1128.69	0.185805373			
Western Province	Colombo	No134, Horana Road, Kesbewa	613.5	334.33	599.05	100.1	203.3	1850.28	0.276309532			
Western Province	Colombo	No.19 A, Horana Colombo Road, Polgasowita	327.412	216.78	437.23	127.59		1109.012	0.246023788			
Western Province	Colombo	Ishangi Enterprises, No.331, Boralugoda, Kosgama	430.58	769.4	515.46	42.03	3.64	1761.11	0.213744608			
Western Province	Colombo	No.19, Horana Rd, Rilawala, Polgasowita	418.71	433.32	504.5	38.7	309.2	1704.43	0.204716533			

Table 5.2: Randomly Selected 8 Stations

Islandwide Fuel Consumption Survey			Petrol						Motor Cyles			
			Motor Cycles	Three wheelers	Cars & S/Wagons	Jeep & Pajero	Passenger Van	Total Petrol Consumption	Using one Sample	Average	Standard Dev	Stdv/(n)^0.5
Province	District	Filling station	Liters	Liters	Liters	Liters	Liters					
Western Province	Colombo	910, Lanka Filling Station, Ranala	1002.24	1396.106	1786.092	72.439	93.67	4350.5465	0.191975786			
Western Province	Colombo	R.C.Wikramarachchi, No.107, Avissawella Rd., Kaduwela	322.785	563.34	302.118	47.19	93.909	1329.342	0.212346349			
Western Province	Colombo	No.131, Bekariya junction, Attidiya	385.928	540.64	1217.99	437.23	555.33	3137.118	0.102516599			
Western Province	Colombo	No.133, New Galle Rd, Moratuwa	251.66	234.6	633.86		8.57	1128.69	0.185805373	0.20	0.051	0.031
Western Province	Colombo	No134, Horana Road, Kesbewa	613.5	334.33	599.05	100.1	203.3	1850.28	0.276309532			
Western Province	Colombo	No.19 A, Horana Colombo Road, Polgasowita	327.412	216.78	437.23	127.59		1109.012	0.246023788			
Western Province	Colombo	Ishangi Enterprises, No 331	430.58	769.4	515.46	42.03	3.64	1761.11	0.213744608			
Western Province	Colombo	No.19, Horana Rd, Rilawala, Polgasowita	418.71	433.32	504.5	38.7	309.2	1704.43	0.204716533			

Table 5.3; Randomly Selected 8 Stations

Islandwide Fuel Consumption Survey			Petrol						Motor Cyles			
			Motor Cycles	Three wheelers	Cars & S/Wagons	Jeep & Pajero	Passenger Van	Total Petrol Consumption	Using one Sample	Average	Standard Dev	Stdv/(n)^0.5
Province	District	Filling station	Liters	Liters	Liters	Liters	Liters					
Western Province	Colombo	No.415, Galle Rd, Ratmalana	793.72	767.64	3116.58	1455.32	715.68	6848.94	0.096574555	0.21	0.109	0.031
Western Province	Colombo	No.184, Galle Rd, Ratmalana	159.68	396.75	440.99	321.4	173.7	1492.52	0.089155701			
Western Province	Colombo	No.133, New Galle Rd, Moratuwa	251.66	234.6	633.86		8.57	1128.69	0.185805373			
Western Province	Colombo	No.300, Horana Road, Miriswatta, Piliyandala	357.22	382.85	1086.1	29.9	42.31	1898.38	0.156809139			
Western Province	Colombo	Filling Station,Pathagama, Hanwella	653.27	660.061	233.59			1546.921	0.351919501			
Western Province	Colombo	No.196, Lower Road, Hanwella	891.921	1078.572	646.76	24.54		2641.793	0.281349636			
Western Province	Colombo	No.27, Colombo Rd, Avissawella	542.092	1185.1	1093.77	41.35	123	2985.312	0.151321984			
Western Province	Colombo	No.138, Raththanapitiya, Boralesgamuwa	692.96	508.59	161.03	52	166.4	1580.98	0.365258679			

Mean values of the selected 8 stations are 0.2, 0.2 and 0.21. For Ho hypothesis to be true the sample mean should be in the range of $0.19<m_2<0.23$. The above randomly selected 8 stations verify that when 8 samples are selected randomly the result will be accurate by the probability of 95%.

5.2.2 Analysis with Randomly Selected 5 Station

Table 5.4: Randomly Selected 5 Station

Islandwide Fuel Consumption Survey			Petrol						Motor Cyles			
			Motor Cycles	Three wheelers	Cars & S/Wagons	Jeep & Pajero	Passenger Van	Total Petrol Consumption	Using one Sample	Average	Standard Dev	Stdv/(n)^0.5
Province	District	Filling station	Liters	Liters	Liters	Liters	Liters					
Western Province	Colombo	910, Lanka Filling Station, Ranala	1002.24	1396.106	1786.092	72.439	93.67	4350.547	0.191976	0.120777	0.043347	0.039355
Western Province	Colombo	Multi purpose cooperative society ltd, Kaduwela	719.285	1101.968	2823.521	65.86	2018.76	6729.394	0.089073			
Western Province	Colombo	No.829, Athulkotte, Mirihana	387.184	475.817	1327.347	51.496	218.045	2459.889	0.131166			
Western Province	Colombo	No.131, Bekariya junction, Attidiya	385.928	540.64	1217.99	437.23	555.33	3137.118	0.102517			
Western Province	Colombo	No.184, Galle Rd, Ratmalana	159.68	396.75	440.99	321.4	173.7	1492.52	0.089156			

Table 5.5: Randomly Selected 5 Station

Islandwide Fuel Consumption Survey			Petrol						Motor Cyles			
			Motor Cycles	Three wheelers	Cars & S/Wagons	Jeep & Pajero	Passenger Van	Total Petrol Consumption	Using one Sample	Average	Standard Dev	Stdv/(n)^0.5
Province	District	Filling station	Liters	Liters	Liters	Liters	Liters					
Western Province	Colombo	Multi purpose cooperative society ltd, Kaduwela	719.285	1101.968	2823.521	65.86	2018.76	6729.394	0.089073			
Western Province	Colombo	No.184, Galle Rd, Ratmalana	159.68	396.75	440.99	321.4	173.7	1492.52	0.089156			
Western Province	Colombo	No134, Horana Road, Kesbewa	613.5	334.33	599.05	100.1	203.3	1850.28	0.27631	0.180861	0.087629	0.039355
Western Province	Colombo	No.19 A, Horana Colombo Road, Polgasowita	327.412	216.78	437.23	127.59		1109.012	0.246024			
Western Province	Colombo	Ishangi Enterprises, No.331, Boralugoda, Kosgama	430.58	769.4	515.46	42.03	3.64	1761.11	0.203745			

Table 5.6: Randomly Selected 5 Station

Islandwide Fuel Consumption Survey			Petrol						Motor Cyles			
			Motor Cycles	Three wheelers	Cars & S/Wagons	Jeep & Pajero	Passenger Van	Total Petrol Consumption	Using one Sample	Average	Standard Dev	Stdv/(n)^0.5
Province	District	Filling station	Liters	Liters	Liters	Liters	Liters					
Western Province	Colombo	No.829, Athulkotte, Mirihana	387.184	475.817	1327.347	51.496	218.045	2459.889	0.131166			
Western Province	Colombo	No.184, Galle Rd, Ratmalana	159.68	396.75	440.99	321.4	173.7	1492.52	0.089156			
Western Province	Colombo	No.300, Horana Road, Miriswatta, Piliyandala	357.22	382.85	1086.1	29.9	42.31	1898.38	0.156809	0.176074	0.101829	0.039355
Western Province	Colombo	Filling Station,Pathgama, Hanwella	653.27	660.061	233.59			1546.921	0.35192			
Western Province	Colombo	No.27, Colombo Rd, Avissawella	542.092	1185.1	1093.77	41.35	123	2985.312	0.151322			

Mean values of the selected 5 stations are 0.12, 0.17 and 0.18.

For Ho hypothesis to be true the sample mean should be in the range of $0.19<m_2<0.23$. The above randomly selected 5 stations verify that when 5 samples are selected randomly the result won't be accurate by the probability of 95%.

5.2.3 Analysis with Randomly Selected 3 Station

Table 5.7: Randomly Selected 3 Station

Islandwide Fuel Consumption Survey			Petrol						Motor Cyles			
			Motor Cycles	Three wheelers	Cars & S/Wagons	Jeep & Pajero	Passenger Van	Total Petrol Consumption	Using one Sample	Average	Standard Dev	Stdv/(n)^0.5
Province	District	Filling station	Liters	Liters	Liters	Liters	Liters					
Western Province	Colombo	910, Lanka Filling Station, Ranala	1002.24	1396.106	1786.092	72.439	93.67	4350.547	0.191976	0.197175	0.014677	0.050807
Western Province	Colombo	No.133, New Galle Rd, Moratuwa	251.66	234.6	633.86		8.57	1128.69	0.185805			
Western Province	Colombo	Ishangi Enterprises, No.331, Boralugoda, Kosgama	430.58	769.4	515.46	42.03	3.64	1761.11	0.213745			

Table 5.8: Randomly Selected 3 Station

Islandwide Fuel Consumption Survey			Petrol						Motor Cyles			
			Motor Cycles	Three wheelers	Cars & S/Wagons	Jeep & Pajero	Passenger Van	Total Petrol Consumption	Using one Sample	Average	Standard Dev	Stdv/(n)^0.5
Province	District	Filling station	Liters	Liters	Liters	Liters	Liters					
Western Province	Colombo	No.133, New Galle Rd, Moratuwa	251.66	234.6	633.86		8.57	1128.69	0.185805	0.226347	0.045982	0.050807
Western Province	Colombo	No134, Horana Road, Kesbewa	613.5	334.33	599.05	100.1	203.3	1850.28	0.27631			
Western Province	Colombo	Badaragama Road, Kesbawa.	313.36	400.457	372.16	88.952	28.86	1203.789	0.216926			

Table 5.9: Randomly Selected 3 Station

Islandwide Fuel Consumption Survey			Petrol						Motor Cyles			
			Motor Cycles	Three wheelers	Cars & S/Wagons	Jeep & Pajero	Passenger Van	Total Petrol Consumption	Using one Sample	Average	Standard Dev	Stdv/(n)^0.5
Province	District	Filling station	Liters	Liters	Liters	Liters	Liters					
Western Province	Colombo	No.27, Colombo Rd, Avissawella	542.092	1185.1	1093.77	41.35	123	2985.312	0.151322	0.303236	0.132297	0.050807
Western P	Colombo	No.138, R	692.96	508.59	161.03	52	166.4	1580.98	0.365259			
Western Province	Colombo	MPCS Ltd, Ingiriya Rd, Padukka	521.58	398.91	152.05	33.08		1105.62	0.393128			

Mean values of the selected 5 stations are 0.19, 0.22 and 0.3.

For Ho hypothesis to be true the sample mean should be in the range of $0.19<m_2<0.23$. The above randomly selected 3 stations verify that when 3 samples are selected randomly the result won't be accurate by the probability of 95%.

6. CONCLUSION

The analysis was carried out in the year 2012 and VKT was calculated for all the vehicle types in Sri Lanka for the year 2012.

Motor cycles have the highest Vehicle Kilometers travelled within the petrol Vehicles. That is about 15.41billion kilometers. The second most highest is Three wheelers and it is about 8.1billion kilometers and third, the cars and wagons and it is about 3.91 billion kilometers. It's clear that the motor cycle usage in Sri Lanka is higher than the other vehicle types. Figure 3.4 shows the breakdown of the VKT for motor cycles. It's well depicted that in Western Province and in North Western Province the motor cycle usage is higher than the other provinces.

VKT of diesel vehicles where the passenger van shows the highest VKT out of all the diesel vehicle types that is about 505.192 million kilometers

Although motor cycle has the highest VKT in Sri Lanka When we consider the VKT per vehicle in the whole country, it reveals that most used vehicle in Sri Lanka is three wheelers where the second most used vehicle is motor cycles. This well depict that Sri Lanka is a third world developing country.

Highest usage of three wheelers is in Western Province and second highest in North Western Province. The minimum usage of three wheelers is in Eastern Province.

Highest usage of cars and Wagons are in Western Province and that is comparatively higher by 5 billion kilometers than all the other provinces and second highest in North Western Province.

Considering the fuel sale in year 2010, 2011, fuel sale growth factor is calculated for the year 2013 and by assuming the vehicle factors that used for the year 2012 is same as the year 2013,then VKT is predicted for the year 2013 for all the vehicle types in Sri Lanka .

The vehicle factor was calculated for different vehicle type in District vise, Provinces vise and Island wide.

To predict the future VKT, vehicle factor, Fuel usage, Fuel consumption rate are required. In the current study in order to find vehicle factor, fuel sales data collected from randomly selected 500 fuel stations in island wide. However repetition of similar exercise in every year would not be economical. Hypothesis analysis was carried out to find the minimum no of survey points which has 95% accuracy. This study reveals that minimum no of survey fuel stations are represented the entire fuel station to the extent of 95% accuracy level.

As a sample calculation the possible number of stations were found for Colombo district for Motor Cycles is 8.

Similarly other vehicle types also can be tested for estimation of vehicle factor by hypothetically and can be found the minimum no of stations that can represent the entire fuel stations in District wise.

7. FURTHER RESEARCH

The analysis was done for the year 2012. In the current study the vehicle factor was found by collecting the fuel sales data from randomly selected 500 sample stations. But it is not economical to perform same exercise in each year to find the vehicle factor. Because the possible 8 stations were found instead of 30 stations from which motorcycle factorcould be estimated to 95% accuracy level in Colombo district. As a future study the possible number of stations in each district for each vehicle type can be computed. Further for this study the VKT of buses was not considered. As a future study this research can be extended with incorporating the VKT of buses.

In this research the vehicular movement within different provinces was not considered. Future research should be carried out with incorporating that factor to get a more precise VKT factor. And if the VKT factor can be found in route vise it will be a great importance in designing routes in future.

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Annex 1

Date : ..... Time (a.m. / p.m.) .....

Fuel Type : **Petrol**

S. No.	Motor Cycles		Three wheelers		Cars & S/Wagons		Jeep & Pajero		Passenger Van	
	Ltr.	Km/ Ltr.	Ltr.	Km/ Ltr.	Ltr.	Km/ Ltr.	Ltr.	Km/ Ltr.	Ltr.	Km/ Ltr.
1										
2										
3										
4										
5										
6										

Date : ..... Time (a.m. / p. m.) : .....

Fuel Type : **Diesel**

S. No.	Three wheelers		Cars & S/Wagons		Pick Up		Jeep & Pajero		Passenger Van		Goods Van		Mini Bus		Bus		Light Truck		Medium Truck		Large Truck		3 Axle Rigid Tk.		3 Axle Art'd Tk.		4 Axle Art'd Tk.		Hand Tracktor		Hand Tracktor	
	Ltr.	Km/	Ltr.	Km/ Ltr.	Ltr.	Km/ Ltr.	Ltr.	Km/ Ltr.	Ltr.	Km / Ltr.	Ltr.	Km/ Ltr.	Ltr.	Km/ Ltr.	Ltr.	Km/ Ltr.	Ltr.	Km/ Ltr.	Ltr.	Km/ Ltr.	Ltr.	Km/ Ltr.	Ltr.	Km/ Ltr.	Ltr.	Km/ Ltr.	Ltr.	Km/ Ltr.	Ltr.	Km/ Ltr.	Ltr.	Km/ Ltr.
1																																
2																																
3																																

Province	District	EE Division	Filling station	Petrol								
				Motor Cycles	Three wheelers	Cars & S/Wagons	Jeep & Pajero	Passenger Van	Three wheelers	Cars & S/Wagons	Pick Up	Jeep & Pajero
				km/ltr.	km/ltr.	km/ltr.	km/ltr.	km/ltr.	km/ltr.	km/ltr.	km/ltr.	km/ltr.
Western Province	Colombo	Colombo	910, Lanka Filling Station, Ranala	59.74286	24.153846	13.0294118	9.5	12.5	31.66667	9.333333	9.5	9.5
Western Province	Colombo	Colombo	Multi purpose cooperative society ltd, Kaduwela	63.9	24.5	14.525	7.25	14.8	36.66667	12	10	9
Western Province	Colombo	Colombo	No.415, Galle Rd, Ratmalana	58.69231	23.807692	10.3461538	5.8	9.842105	32.76923	10.35938	12.37037	11.73929
Western Province	Colombo	Colombo	No.133, New Galle Rd, Moratuwa	53.57143	24	10.7241379		11	32.81818	11.875	13	8.5
Western Province	Colombo	Avissawella	No134, Horana Road, Kesbewa	53.47619	27.652174	11.7142857	12	12	26	11.05882	9	10
Western Province	Colombo	Avissawella	B&S Auto Enterprises Pvt Ltd, No.160, High Level Rd, Homagama	56.40741	28.153846	11.4736842	11.25	11.33333	35.71429	11.6	10.111111	10.8
Western Province	Gampaha	Gampaha	No.09, Yakkala Road, Gampaha	49.94286	24.4286	13.4667	30	13	35.66667	13.25	8.675	12.5
Western Province	Gampaha	Gampaha	Piyadasa & sons, Minuwangoda	50.45455	28	12.25	23	16.33333	29	15.5	11.833333	10.33333
Western Province	Gampaha	Negombo	Lanka Filling Station, Tudella, Ja-Ela	57.64706	29.558824	11.5714286		10.2	29.5	14.71429		14
Western Province	Gampaha	Negombo	Lanka Filling Station,Kanuwana, Ja-Ela	49.62963	29.444444	12.8181818		11.46667	30	15.36364		15.5
Western Province	Gampaha	Nittambuwa	MPCS, Attanagalla(Veyangoda)	49.31429	26.114286	16.5151515	13	14.42857	35.41667	20	8.6666667	8
Western Province	Gampaha	Nittambuwa	Co-op Filling Station,Giridara	63.85714	25.685714	11.3793103		14	33.6	14.75	10.571429	10.5
Western Province	Gampaha	Nittambuwa	Co-op Filling Station,Kiridiwela	61.714	23.5	13.6666667		20				
Western Province	Kalutara	Kalutara	No.436, Kalutara North	53.52381	26.769231	13.6666667		14	21.5	8.5	14	13
Western Province	Kalutara	Kalutara	No.400, Sagana Enterprises, Galle Rd, Kalutara North	58.78125	27.125	12.7272727		15.33333	33.66667	13		13
Western Province	Kalutara	Agalawatta	Bellana, Agalawatta	58.23077	30.132857	9.75	7.25	15	26.11111	6.3125	13	7.625
Western Province	Kalutara	Horana	Horana Road, Bulathsinghala	62.85714	27.971429	14.4375	8.75		31	13	10.5	9.5
Central Province	Kandy	Kandy	Gunaratne Enterprises, Pujapitiya, Kandy	50.78571	23.4	16	17.5	10	33	13		13.5
Central Province	Kandy	Kandy	Hadeniya,Wenrallagama	60.71429	25.526316	13			33.7	14.33333	12	13.5

Annex VI

	DISTRICT WISE SALES					
	2010 (01.04.2010-31.04.2010)		2011		2012	
	PETROL	DIESEL	PETROL	DIESEL	PETROL	DIESEL
Kandy	23,525,700	49,269,000	36,715,800	81,737,700	42,489,769	85,462,712
Matale	8,121,300	19,598,700	12,713,055	34,838,100	13,873,200	34,062,600
Nuwara eliya	4,897,200	15,506,700	7,877,100	27,792,600	8,487,600	24,334,200
Batticaloa	7,458,000	14,526,600	11,114,605	22,383,900	13,173,600	25,481,960
Ampara	13,308,041	28,122,600	18,493,200	37,481,400	19,608,600	40,972,800
Trincomalee	5,464,800	19,555,800	7,728,600	31,148,700	9,236,739	26,832,339
Anuradhapura	20,889,000	45,107,700	31,219,875	75,111,300	35,418,900	81,574,698
Polonnaruwa	9,750,276	25,126,200	14,044,800	37,884,000	15,094,200	40,887,000
Jaffna	9,860,400	16,665,000	16,536,300	29,412,900	19,661,400	34,699,500
Mannar	1,329,900	5,250,300	2,003,100	7,108,200	2,121,900	8,411,700
Mulalativu	198,000	1,531,200	953,700	6,088,500	2,554,200	13,823,700
Vavuniya	2,214,300	8,801,100	3,455,100	22,258,500	3,689,400	27,934,500
Killinochchi	788,700	3,039,300	2,323,200	8,768,100	2,824,800	10,777,800
Kurunegala	43,896,290	79,140,600	66,336,595	125,938,090	72,438,300	129,921,355
Puttalam	22,494,365	44,909,435	32,610,600	71,227,200	32,468,700	65,102,400
Ratnapura	19,024,500	39,972,900	28,201,960	64,771,878	31,026,600	68,630,100
Kegalle	14,117,400	26,512,200	21,892,200	42,663,888	23,868,900	43,820,700
Galla	20,829,600	35,574,000	31,960,322	63,792,793	37,151,400	64,864,800
Matara	11,938,323	49,567,417	18,449,416	80,745,874	19,872,600	68,425,500
Hambantota	11,078,100	31,109,100	16,642,895	55,248,600	17,391,000	50,553,782
Badulla	9,385,200	22,321,200	14,289,000	39,378,900	15,800,400	40,481,100
Moneragala	8,438,430	20,182,470	13,084,500	30,541,500	12,718,200	29,099,400
Colombo	112,642,200	141,018,900	169,982,466	257,316,476	184,807,107	249,223,425
Gampaha	73,293,014	128,831,011	111,927,809	219,337,800	123,871,491	226,426,389
Kalutara	24,763,200	43,335,600	38,029,200	76,074,900	41,556,900	74,589,944

Annex IV

From MCC data from Planning Division RDA

Hour	Average (Week Days) (1 – 5)	Average Entire week
0000 -0100	161	191.3
0100 - 0200	87.6	105.7
0200 - 0300	54	74.7
0300 - 0400	51.4	61.9
0500 - 0600	233.8	217.9
0600 - 0700	1326.4	191.6
0700 - 0800	2387	1819.3
0800 - 0900	2432	1990.3
0900 - 1000	1742.4	1674.3
1000 - 1100	1748.8	1832.7
1100 - 1200	1870.6	1842.6
1200 - 1300	1885.4	1864.0
1300 - 1400	1857.2	1794.9
1400 - 1500	1786.6	1699.0
1500 - 1600	1679.8	1607.1
1600 - 1700	1859.2	1743.9
1700 - 1800	2341	1956.3
1800 - 1900	2327.6	1891.3
1900 - 2000	1736.4	1325
2000 - 2100	1288	1042
2100 - 2200	806.4	604.0
2200 - 2300	511	514.4
2300 - 2400	319.4	334.4
	30584.8	**26471.6**

Night Factor	**1.2**