Estimation of Vehicle Kilometers Travelled in Southern province, Sri Lanka

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Abstract— **Estimation of vehicle kilometers travelled (VKT) is used in traffic and transport planning for various purposes such estimating the emissions, estimating energy consumption, analyzing crashes, assessing traffic impact, and making road safety policy. Therefore, it is crucial to have an accurate timely estimation of VKT. Both traffic and non–traffic measurement methods are popular among the transport planners and researchers. Very few studies have conducted in Sri Lanka for estimating the VKT. This study proposes to estimate the VKT based on the number of household daily trips, which are collected through the interviews. The interviewer records the mode of travel, total number of kilometer travelled, and number of passengers. The socio-demographic information is also collected and this includes age, gender, employment status, income and residential area. The estimation of total VKT are derived from survey respondents' total number of kilometers each travelled during the previous 12 months in Southern Province, Sri Lanka. The collected data are also used to estimate the personal kilometer travelled and characteristics of travelers in Southern Province.**

Keywords— Vehicle Kilometers travelled

I. INTRODUCTION

Transport is a vital link that moves people and goods across the country. According to Carlos and Joao's views, the travel distances, comfort, freedom to choose travel destination and travel routes, which are the most considered factors of transportation mode choice in the estimation of current transport demand [1]. The selection of mode choice and route are important for several important activities. Some of they are modeling the safety and environmental impacts of road transportation, estimating the performance indicators of road networks, estimating the vehicle fleets, investing for infrastructure, estimating vehicle emissions, computing energy consumption, analyzing mobility and accessibility within the framework of land use policy setting, and assessing economic of road systems.

Vehicle Kilometers Travelled (VKT) refers to the total kilometers travelled by vehicles on a roadway. Measuring and forecasting traffic growth, in terms of VKT is a key element in strategic transportation planning process for resource allocation, infrastructure investment, estimating emissions, and fuel consumption. Moreover, VKT is the most often used consideration in traffic and transport planning for various purposes such as allocating resources, estimating vehicle emissions, estimating energy consumptions, analyzing crashes, assessing traffic impact, and making road safety policies. Therefore, it is crucial to have an accurate timely estimation of VKT. For many years back, after the World War II, Vehicle Miles Travelled (VMT) had increased steadily [2]. In addition, the first time in many developed countries, a sudden increase in vehicle had occurred and the demand for mobility had increased in 20th century.

In current world, many of the developed countries like United Kingdom (UK), United States (U.S.), and Australia estimate VKT to measure the road network or the vehicle fleet usage of its country. Every year the department of transport, UK estimates VMT by vehicle types, road category, and region. German estimated VMT in UK by using traffic-based method and taking traffic data by vehicle at around 8,000 manual counts over 12 hours period [3]. According to 2013 and 2010 transportation data, 90% of passengers travelled by road and 68% of freight goods moved by roads in UK. Therefore, the road transportation was the main transport mode for individuals and businesses in UK. In 2014, VMT was 10 time higher than in 1949 due to the long-term trend of traffic. VMT data are key source of information for country's infrastructure and main uses for transport modeling, local transport planning, road crash and safety statistics, and the public users. Moreover, local authorities and governments used VMT data for transportation planning, road engineering, and policy monitoring at regional or to the local level. Focusing on economic and demographic trends, several studies in the literature suggested that a decline in vehicle travel might have happened due to various reasons. Therefore, having an accurate estimation of VMT is much important as a key point for country's infrastructure development.

In Australia VKT is one of the main variables used as measure of a road network since road transport is the dominant mode of transportation. Gargett and Hossain estimated VKT in Australia by taking state and territory fuel sales data [4]. The estimation of VKT by state and territory is required for planning purposes, environment monitoring, crash analysis, highway fund allocation, trend extrapolation, and estimation of vehicle emissions. Moreover, the estimation of VKT

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contributes information necessary to inform infrastructure investment decisions and road safety policy. The VKT data by each vehicle can also be used for benchmark policy decision about road fund allocation based on traffic trends. Further, these data can behoove to better for understanding the future transportation behavior and provide crucial information on traffic volumes and the growth of traffic around Australia.

A. Road transport sector in Sri Lanka

Rising population, economic changes, and introduction of modern technologies lead to the evolution of transport system. Highways, flyovers, and bridges are being built to cater to increasing volume of traffic in Sri Lanka. Focusing on the cost of fuel is important when assessing the economics of transport. In countries like Sri Lanka most vehicles, fuel and road technologies are imported. Therefore, rising oil price has a significant impact on the cost of transport. Even though variety of transportation modes are available in the country though road transportation is the primary and preferred mode of transportation. Road transportation is integral to the ongoing development of the Sri Lankan economy and enhances the mobility and quality of life of citizens. Based on 2015 data reported by Ministry of Transportation and Civil Aviation, about 6 million motor vehicles are on the Sri Lankan roadways. As Figure 1 illustrates, 53% are made up with motorcycles and remaining compromising with motor cars, three-wheelers, buses, dual – purpose vehicles, motor lorries, land vehicle tractors, and land vehicle trailers. In Sri Lanka very few studies were conducted for estimating the VKT, but timely data on VMT could not be found.

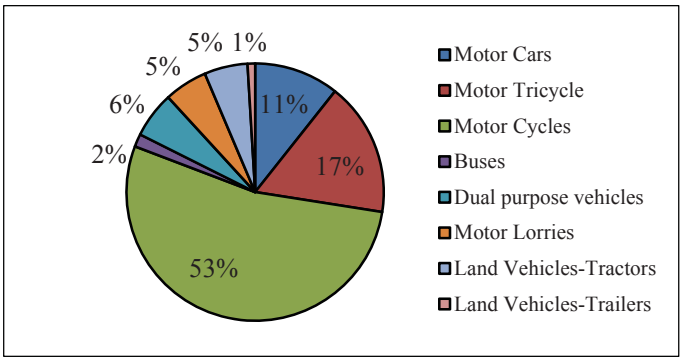

Fig. 1. Proportion of vehicle types in Sri Lanka, 2015

Both traffic measurement methods and non–traffic measurement methods are popular among the transportation planners and researchers for estimating VKT. Fuel usage method and traffic model methods are non – traffic count based methods. VKT of Sri Lanka was estimated by Jayasekera using fuel usage method [5]. That gave the VKT of vehicles on the highway system during a given period.

The current study proposes to estimate of total VKT by derived from survey respondents and estimate the total number of kilometers each travelled during the previous 12 months in Southern Province; Sri Lanka. Moreover, the variations in VKT among males and females, different age categories, residential areas, monthly household income, and current status are identified. In addition, estimation of the person kilometers travelled (PKT) are carried out investigating the characteristics of travelers in the study area.

II. Literature Review

A. Traffic count based VKT estimation approaches

This method is the currently most preferred method because it uses actual data on vehicle moments. Fricker and Kumapley estimated the VMT using the Highway Performance Monitoring System (HPMS) based method in Indiana [6]. The data collections were classified as urban and rural. Also, vehicles were classified in to 13 vehicle types: motorcycles, passenger cars, other two-axle four-tire single unit vehicles, buses, two-axle four-tire single unit trucks, three-axle single unit trucks, four or more-axle single-unit trucks, four or less- axle single unit trucks, five-axle single unit trucks, six or more-axle single unit trucks, five or less-axle multi trailer trucks, six-axle multi trailer trucks, and seven or more-axle multi trailer trucks. This HPMS program required three types of data such as universe data, area-wide data, and sections data. The VMT on a road segment can be estimated by multiplying the values of average annual daily traffic of the segment and centerline mileage of it. Centerline mileage is equal to the length of the road section. The VMT calculation process carried out by using a subprogram of the HPMS submittal software that calculated VMT in a 24-hour period. There are some disadvantages of this method. VMT estimates from HPMS method does not represent the total since it does not estimate VMT of local roads. Due to the selection of sites for counting process and incomplete traffic counts errors may occur in this method.

The U.S. Department of Transportation used traffic count based method to estimate VKT in local functional roads [7]. The steps for the estimation were preparation of sample frame, estimation of sample size requirements, selection of sample sections, collection of traffic volume data, estimation of local VKT, and finally estimation of precision of VKT estimates. The boundary of research was selected covering the areas with population greater than 200,000 and urban or rural area in a state. Traffic counts were carried out using standard counting procedures. Count data collected by installing the equipment in every sections in 24 hours. To reduce the errors of the data recounts were carried out on the same day of the week. To estimate VKT an actual count and length of the section in each section was taken. Simply VKT can be estimated by multiplying the count by the length of the each section. The results showed that estimated daily VKT was 15,197.3 with precision of plus or minus 2.6 percent with 95 percent confidence [7].

B. Fuel use based VKT estimation approaches

Fricker and Kumapley estimated VMT using fuel use method taking fuel cost of driving per mile while considering

retail information in diesel and gasoline, vehicle type, and price per mile of vehicle travel [6]. Estimating the miles per gallon was the most difficult task as it depends on many variables like; condition of the vehicles, driving patterns, weather condition, and the topography. Data were not accurate to estimate VMT of all vehicle types since fuel efficiency of vehicle types were utterly different. From year 1992 to 2001, the total price of fuel: in gallons, in state of Indiana increased drastically from 593,050 to 945,848 for these 10 years. Due to this different unit price of fuels in different states, it was hard to estimate the amount fuel brought to the state. Therefore, this method was not a good method to estimate VMT.

A recent study done by Fukud estimated VKT and fuel efficiency by taking odometer readings [8]. Sedan (passengers not more than 7), van, pickup trucks, and motorcycles were selected as the target vehicle types to carry out the research. Questionnaire survey was conducted in order to collect data for the study. Study consisted with two phases, the first part mainly focused about the vehicle information including vehicle age, records of odometer, fuel type, and vehicle condition. From the second phase mainly focused on information of driver like gender, age, personal income, household income, occupation, and residential location. In this study questionnaire form distributed in main, three gas stations. To obtain the fuel consumption data, the driver should filled fully fuel and refill fully for the second time in the same station. The results showed that with the vehicle age increase with the accumulated VKT but the rate was decreasing year by year. The driver data illustrated that the drivers with higher income accumulate higher VKT. Therefore, the vehicle type, fuel type, and driver's income significantly influenced to the annual VKT of vehicle.

C. Traffic model based VKT estimation approaches

Moreover, Fricker and Kumapley estimated VMT using traffic model method in Indiana [6]. The main objective of the study was to simulate the amount of traffic on each roadway, using information of housing patterns, employment patterns, and roadway capacity. Population; employment; and land-use data; personal and household characteristics like income, vehicle ownership, and license status data were needed to estimate the VMT. Household travel characteristics can be determined using data of average annual miles driven by licensed driver by gender, age, average miles driven in area, the behavior of trip making person and household characteristics. These data were collected by distributing questionnaire to road-users and getting responds to them. Moreover, the data collected by conducting face–to–face interviews for a given time period. Then VMT was estimated by multiplying the values of average annual mileage per household with population of household. The accuracy of questionnaire data were thus questionable because of data were mainly depended on the responses of road users. However, this method can give an agreeable value for VMT.

The Household Travel Survey in Sydney is the largest and most comprehensive source to estimate personal travel data [9]. The household travel survey is consisted of face–to–face interviews and carried out every day from July to June of each year. Each householder uses a simple travel diary to record the details of all travel undertaken in every day. Then an interviewer conducts face-to-face interviews with each householder to collect the details of each trip. The interviewer records the mode of travel, trip purpose, start and end location, and time of departure and arrival. Detailed socio-demographic information is also collected and this includes dwelling type, household structure and vehicle details, as well as age, gender, employment status, occupation, and income of individual household members. About 5,000 randomly selected households are approached each year to participate in the survey. In the household travel survey, data on people and households, public transport use, vehicle use, and non – motorized modes were gathered. From the collected data through household travel survey the VMT in Sydney area in the given year can be estimated. According to this approach, the surveys may contain inaccurate information provided by responders and can only forecast a rough estimation of VMT.

III. METHODOLOGY

The VKT can be varied corresponding to age, gender, mode of travel, trip purpose, vehicle details, employment status, occupation, and income of individual household members [9]. Therefore, age, gender, employment status, household monthly income, and residential area factors were selected to investigate the variation of VKT. All trips made by households throughout the weekdays, weekends and yearly were studied.

Initially a pilot study was conducted by distributing 50 questionnaires to random road users in Southern province and subsequently determined the sample size of the household travel survey using Equation 1.

$$\text{Sample size} = \frac{\text{Coefficient of variation}^2 \times \text{Standard normal variant}^2}{\text{Level of accuracy}^2} \quad (1)$$

Data collected from the pilot study was used to estimate the sample size and came up with 224 users assuming 90% of level of accuracy. Then estimates of VKT were done from survey respondents' information on their travel during previous 12 months. The estimated VKTs of each traveler were multiplied by weightages to obtain the total VKT values. The estimation of weightages was carried out considering the population data on age, gender, employment status, and residential area. Weighted VKT was estimated for each vehicle type for the year 2016 based on the survey carried out in the same year. Using the data from the 2012 island-wide household survey conducted in Sri Lanka, the census for 2016 by gender, age category, residential area, and employment status for Southern Province were predicted and tabulated in Table I. Since the variation of annual birth, annual death, and the difference of migration and immigration; population variation could be expected from year 2012 to 2016 but it was assumed that the population in 2016 mostly same as the 2012 population.

Then, collected data were used to estimate the Person Kilometers Travelled (PKT) and variation of travel characteristics were identified.

TABLE I. ESTIMATED POPOLATION OF SOURTHN PROVICE FOR 2016

Variables	Categories		Numbers	Percentages
Gender		Male	124,000	49
		Female	129,000	51
Age Category (years) and Gender	15 - 24	Male	56,000	22
	25 – 34	Male	89,000	35
	35 – 44	Male	48,000	19
	45 – 54	Male	46,000	18
	55 – 69	Male	15,000	6
	15 - 24	Female	56,000	22
	25 – 34	Female	53,000	21
	35 – 44	Female	48,000	19
	45 – 54	Female	46,000	18
	55 – 69	Female	51,000	20
Current status and Gender	Employed	Male	177,000	70
	Unemployed	Male	76,000	30
	Employed	Female	66,000	26
	Unemployed	Female	187,000	74
Residential area	Urban		28,000	11
	Rural		225,000	89

IV. RESULTS

A. Yearly VKT and PKT Estimates

The estimated yearly VKT data are presented in this section by gender, age category, and other categories. As shown in Figure 2, males travelled more compared to females in southern province. PKT per a female was 3,862 and for a male it was 6,871. When compared to VKT with PKT, PKT values were higher both males and females, this may be because people travel more as passenger than driver.

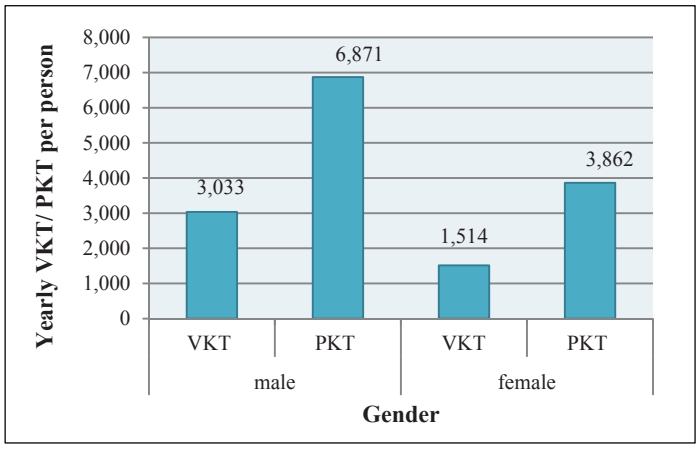

Fig. 2. Weighted VKT and PKT of southern Sri Lanka by gender during 2016

As shown in Figure 3, people age between 25 and 34 years travelled more compared to other people. This may be because they were most active people who make chain of trips to their offices, to school with children, to shops, and etc. People in age between 55 and 69 years travelled less this may be because they make shorter trips. The young people age between 15 and 24 years travelled more compared to people at age between 55 and 64 group. Young people make mostly education trips. Elderly people travelled less, this may be because the most of the time they stay at home.

As shows in Figure 4, the VKT per employed person was 6,871 and for unemployed person it was 3,862. VKT of employed people was high compared to unemployment people and same was observed in term of PKT.

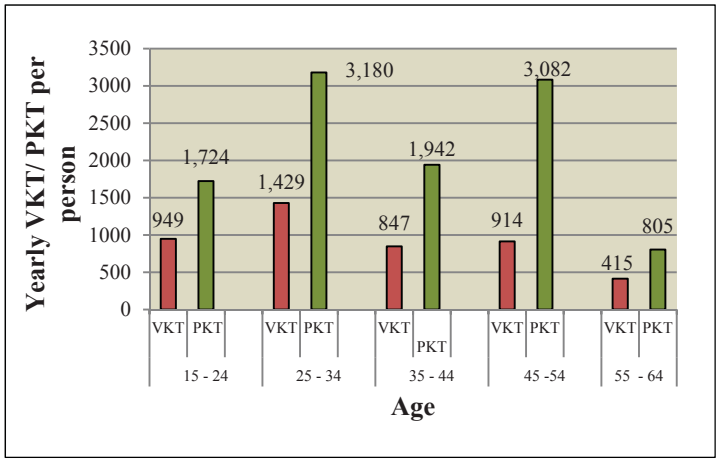

Fig. 3. Weighted VKT and PKT of southern Sri Lanka by age during 2016

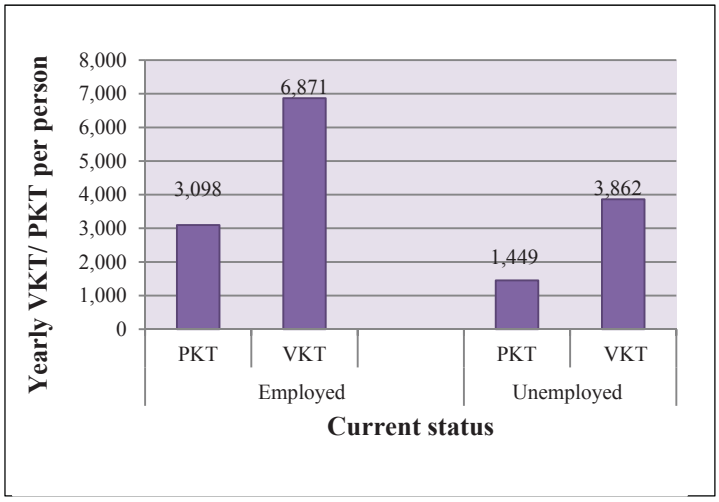

Fig. 4. Weighted VKT and PKT of southern of Sri Lanka by current status during 2016

As shows in Figure 5, an urban residential person travelled 701 Km and a rural residential person traveled 3,846 Km during the year. An urban passenger travelled 1,725 Km and a rural passenger travelled 9,009 Km. Therefore, an average passenger travelled more compared to an average driver in both urban and rural areas. This may be because many of the main schools, hospitals, offices are located in urban areas therefore a person from rural area have to travel more compared to person lived in urban area.

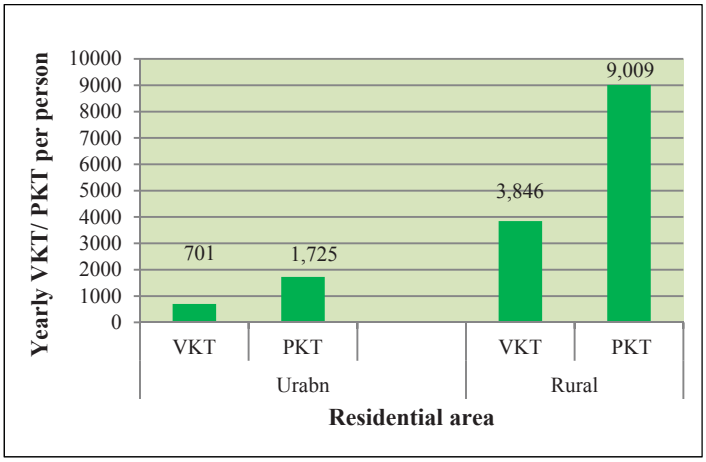

Fig. 5. Weighted VKT and PKT of southern Sri Lanka by resident area during 2016

The monthly household income was categorized in to 9 categories as shows in Figure 6 and 7. Figure 6 the weighted VKT values based on the monthly household income category. The people income in between LKR 150,000 and 175,000 drove more compared to other categories. As shown in Figure 7, people whose monthly income in between LKR 125,000 and 150,000 travelled more compared to others.

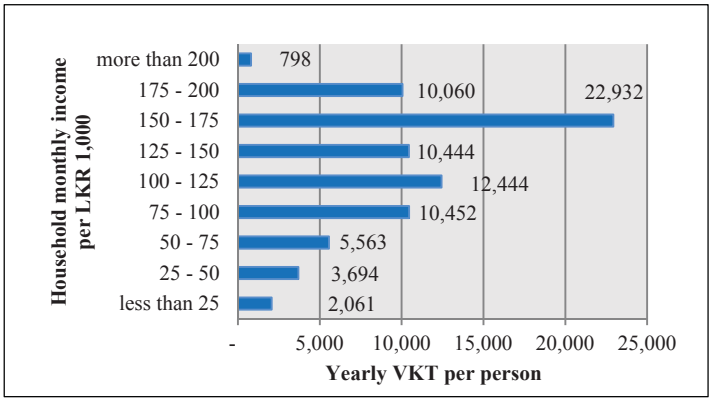

Fig. 6. Weighted VKT of southern Sri Lanka by monthly household income during 2016

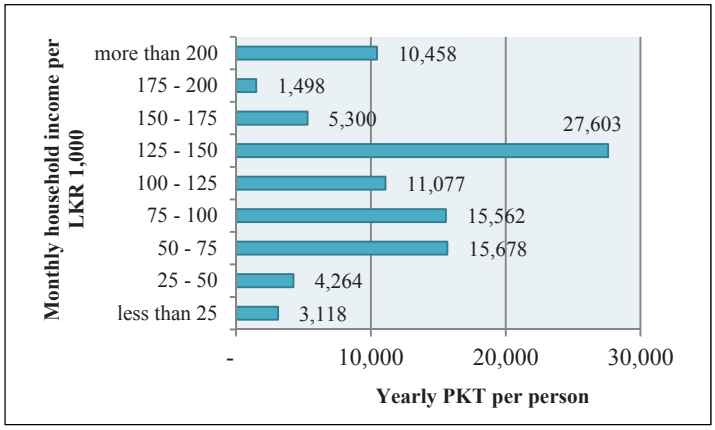

Fig. 7. Weighted PKT of southern Sri Lanka by monthly household income during 2016

B. Classification of travelers in Southern province

Travel behaviors of people varied with the preference of mode they use. The modes were categorized into eight categories; walking, car, van, jeep, motorcycle, three-wheeler, and bicycle. As shows in Table II, males travelled more compared to females. Males selected cars as their frequent transportation mode while most selected mode for females was motorcycle. Moreover, females walked more compared to males. The usage of jeep was very less for both males and females compared to other modes.

TABLE II. CLASSIFICATION OF WEIGHTED PKT OF SOUTHERN SRI LANKA BY GENDER DURING 2016

Variable	Categories	Mode	Weighted yearly PKT (Km)
Gender	Male	Walking	50
		Car	2,225
		Van	2,192
		Jeep	27
		Motorcycle	1,315
		Three-wheeler	841
		Bicycle	60
	Female	Walking	103
		Car	706
		Van	1,130
		Jeep	1
		Motorcycle	1,223
		Three-wheeler	464
		Bicycle	11

As shown in Table III, employed people frequently used van as their mode of travel and unemployed people frequently used motorcycles as their mode of travel.

TABLE III. CLASSIFICATION OF PKT OF SOUTHERN SRI LANKA BY CURRENT STATUS DURING 2016

Variables	Categories	Mode	Weighted Yearly PKT (Km)
Current status	Employed	Walking	29
		Car	2,168
		Van	2,545
		Jeep	29
		Motorcycle	1,514
		Three-wheeler	863
		Bicycle	12
	Unemployed	Walking	125
		Car	763
		Van	776
		Jeep	6
		Motorcycle	1,023
		Three- wheeler	442
		Bicycle	160

Urban and rural residencies were used van more frequently as shown in Table IV. But the kilometers they travelled were higher for rural residencies. Rural residencies travelled more kilometers with more passengers compared to urban residencies. As shows in Table V, people at the age between 15 and 24 travelled more by motorcycles than other modes. The most frequent mode of people at age categories of 25 – 34 years and 45- 54 years was van. The most frequently mode of people at age between 35 and 44 was car and van was the most frequent mode of people in between 45 and 69 years.

TABLE IV. CLASSIFICATION OF PKT OF SOUTHERN SRI LANKA BY RESIDENTIAL AREA DURING 2016

Variables	Categories	Mode	Weighted Yearly PKT (Km)
Residential area	Urban	Walking	22
		Car	426
		Van	620
		Jeep	35
		Motorcycle	455
		Three-wheeler	128
		Bicycle	15
	Rural	Walk	132
		Car	2,505
		Van	2,702
		Jeep	-
		Motorcycle	850
		Three-wheeler	1,176
		Bicycle	156

TABLE V. CLASSIFICATION OF PKT BY AGE CATEGORY DURING 2016

Variable	Categories	Mode	Weighted Yearly PKT (Km)
Age category in years	15 - 24	Walking	87
		Car	195
		Van	285
		Jeep	-
		Motorcycle	881
		Three-wheeler	75
		Bicycle	48
	25 -34	Walking	18
		Car	487
		Van	1,020
		Jeep	-
		Motorcycle	789
		Three-wheeler	780
		Bicycle	11
	35 - 44	Walking	33
		Car	1,096
		Van	245
		Jeep	-
		Motorcycle	110
		Three-wheeler	414
		Bicycle	2
	45 - 54	Walking	4
		Car	776
		Van	1,714
		Jeep	26
		Motorcycle	110
		Three-wheeler	25
		Bicycle	100
	55 - 64	Walking	13
		Car	377
		Van	57
		Jeep	-
		Motorcycle	339
		Three-wheeler	7
		Bicycle	11

CONCLUSIONS

This research mainly highlights the variation of VKT and PKT while classifying them with respect to socio demographic information such as gender, age, monthly household income, residential area, and employment status. Accordingly household travel survey was carried out to estimate the kilometers travelled by travelers during a year. It was found that male drivers and passengers travel more kilometers compared to females in Southern province. Moreover, males frequently used cars as their transportation mode while female used motorcycles. Although the vehicle usages for males were high, their walking distance was less. The people in age group of 25 -34 years travelled more because they may make chain of trips like trips to their offices, to schools, to shop etc. In addition, the most preferable mode of them was van. Moreover, the people in age between 55 and 64 years travelled less may be because the most of the time they stay at home. Also, they preferred to use car as their transportation mode due to comfort. Employed passengers travelled more and preferred to use vans. Unemployed travelers preferred to use motorcycles. When considered the residential area, rural residencies travelled more using vans. Rural people had to travel more compared to urban people because many of the school and offices were situated proximity to the city. According to the monthly household income, high-income group travelled more compared to other categories and they frequently used cars.

Moreover, estimation of VKT is beneficial for the country in infrastructure development, estimating emissions, road safety policy, and traffic and transportation planning. Errors might occur in this study as the data depend on the responses of the road users. However, these data can behoove to better for understanding the future transportation behavior and provide crucial information on traffic volume and the growth of traffic around Southern province.

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