Validation of Household Travel Survey Based Vehicle Kilometer Travelled Estimation Method Proposed for Developing Countries

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Abstract: Vehicle kilometer travelled (VKT) is the total number of vehicles travelled on the road in kilometers. VKT is mostly used in transportation planning for allocating resources, estimating vehicle emission, assessing of traffic impact, analyzing crash statistics, and some necessary information for road policy. This study validates the estimates of VKT from household travel survey method by comparing them with VKT estimates using Average Daily Traffic (ADT) data. The method was validated using the data collected from Uva province of Sri Lanka during July 2020. Additionally travel distances by different modes and Personal Kilometers Travel (PKT) were estimated. Results showed that VKT estimates using ADT data was not significantly different to the VKT estimates using household travel survey (p=0.342). Therefore, household travel survey is a promising method to estimate the VKT for developing countries where ADT data is not regularly collected. Moreover, this method provides mode specific information and PKT data.

Keywords: Traffic data collection methods, Vehicle kilometers travelled, Vehicle Mile Travelled, Personal kilometers travelled, Mode choice characteristics

1. INTRODUCTION

Road transportation is a crucial element for economy and social relationship which is a link of transporting goods and people around countries. However, the increase of vehicle usage results environmental pollution, traffic congestion, and accidents. VKT estimation is an indicator of vehicle usage that gives the total number of vehicles travel in kilometers on the road. VKT data are used for traffic and transportation planning by allocating resources, estimating vehicle emission, assessing of traffic impact and some necessary information to contribute to the road policies. VKT estimation were also classified into two categories (Fricker and Kumapley, 2002). Those are non-traffic count-based method and traffic count-based methods. Traffic volume count method and odometer meter reading method were used for finding Annual Average Daily Traffic (AADT) and estimate the VKT by accumulation of their multiplications of the length of the road in traffic count method. Traffic count-based method consists of driver-hold survey, household survey or fuel station survey. In these types of data collection used sample questionnaire which sent to households, driver-hold or fuel station survey for getting various information and analyze data to find the VKT.

One of main variables used for road network measurement is VKT, since vehicle transport is the powerful mode of transportation in Australia (Hossain and Gargett, 2011). Fuel sales data were used to estimate VKT in Australia. Planning Purposes, monitoring of environment, crash analysis, allocating fund for highways, trend extrapolation and estimate emission of vehicles required VKT estimates categorizing by state and territory. Other than that, VKT contributes

crucial data to invest decisions, traffic planning and for developing road safety policies.

Most VKT estimation methods under homogeneous traffic conditions in developed countries cannot be used in developing countries due to the heterogeneity of traffic conditions. Inadequacy of data such as traffic volume data, geometric data weaken VKT estimations in those countries. Developing countries like Sri Lanka do not have mechanism to collect the traffic volume data for estimating VKT regularly. Those countries do not have permanent traffic counting stations to collect traffic volume data or weighting data and those data are collected based on the requirement of oncoming construction and rehabilitation projects. That may be because the funding is not available or not enough to collect the data regularly. Therefore, most probably in developing countries, mainly the economic viability of transportation projects is assessed focusing current trends and future growth scenarios. The periodic estimations of VKT data is a current need for developing countries with heterogeneous traffic because accurate policy decisions in transportation sector would lead to rapid economic development of the country. The periodic VKT estimations are comparatively less in those developing countries may be due to lack of funding allocations for implementing the estimating techniques and the less awareness or knowledge among the transportation communities. Travel diary surveys, odometer surveys, and questionnaire surveys seem flexible in those developing countries. Gunathilake and Amarasingha (2020) proposed VKT estimation trough household travel surveys as an alternative method for developing countries like Sri Lanka. Proposed method is a questionnaire based household survey method in order to obtain weekly travel information of respondents including special yearly trip information, and then data were aggregated and weighed to come up with yearly VKT. Gunathilaka and Amarasingha (2020) argue that the proposed method is practical and cost effective; however, this method has not been validated or assessed. The main objective of this study was to validate the proposed method using ADT data through a case study. The validation of the proposed method is needed before using estimates for transportation planning and policy decisions.

2. LITERATURE REVIEW

VKT and PKT the important estimations for transportation system were studied in southern province, Sri Lanka by Weerasekara and Amarasingha (2017). The objective of this research was to estimate VKT and PKT in Sothern province and mode of travel by different travelers. In this research questionnaire method was used. Data were collected such as age, gender, monthly income, and residential factors for all trips made by households. Data were collected in 2016 in the southern province. In this study, data from 224 questionnaires which were distributed randomly to households were used. When comparing males versus females, males travelled more. People in between 55 and 64 years travelled lesser distance and people in 25-34 age category travelled higher distance. In rural residential areas VKT and PKT were lower compared to that of urban areas. Finally, this research provided the information regarding transportation behavior and provide crucial information on traffic growth at southern province.

Amarasingha and Balasayanthan (2018) investigated the travel characteristics, VKT, and PKT in Jaffna, Sri Lanka. Roads of Jaffna district were damaged during the Garilla war and therefore roads were under renovation at the time of data collection. In this study, data were collected through household travel survey. Travelers' information, mode of transport, travel distance in the district were collected during July 2017. Results showed that male and female VKT value were 2,144 km and 408 km. PKT values were 5,590 km for male and female PKT was 730 km in year 2017. VKT and PKT of males were significantly higher than that of females as percentage. About 80% of the people in Jaffna lived in rural area according to collected data.

VKT in rural residential area was 405 km and VKT for area that was 408 km in 2017. PKT of the rural areas was 5,241 km and in urban area, it was 1,080 km. This survey was very important for transport planning in Jaffna district, Sri Lanka.

Fukuda et al. (2013) conducted driver interview survey and odometer data analysis for estimating VKT by vehicle type in Thailand aiming to calculate the CO_2 emissions. In this study VKT models were developed different type of vehicles of Sedan, Van and pickup truck, and motorcycle. The VKT models investigate the relationship between accumulated VKT and vehicle age. Results showed that accumulated VKT significant positive relation with vehicle age. However, the annual VKT showed significant negative relation with vehicle age. When investigating the annual VKT for Sedan by fuel type, it has been revealed that the VKT values were 21,230; 23,230; and 26,304 km for except CNG and Diesel vehicles, diesel vehicles, and CNG (Bi-fuel) vehicles respectively. Annual VKT value for gasoline 91 motorcycles was 6,664 km and gasohol 91-E10 motorcycles it was 6,808 km. The vehicle type, fuel type, and driver's incomes were identified as significant factors which effect for both accumulated and annual VKT of vehicle.

Road transportation is the highest contributor of energy consumptions with the usage of fossil fuels and contribution to greenhouse gas emissions globally (Sierra, 2013). The objectives of this research were to estimate VKT to find the energy consumption by road transportation and by vehicle type. A VKT survey was conducted in Ecuador in year 2012. The data was collected from international and national sectors like National Traffic Agency of Ecuado, Bureau of Infrastructure, Transport and Regional Economics of Australia etc. As result of this study highest energy consumption was in heavy vehicles (42%) and lowest one was in motorcycles (2%). Passenger transport energy consumption was 18%. Approximately 14.3 million tons of CO_2 in 2012 released to atmosphere as greenhouse gas. It was identified the groups of vehicles with higher fuel consumer in the road transport sector. The results will be helpful in public organizations for better public policy making and to ensure the efficient energy consumption.

Estimates of emission consumption and vehicular parameters of energy consumption were not entered to transportation system in India (Goel et al., 2015). As a result of this research, vehicular use parameters– in-use fleet size, annual mileage and fuel of efficiency of cars and Motorized two-wheelers (MTW), except fleet size and annual mileage of cars were found. Fuel station survey and secondary data sources were used for this research around Delhi, Visakhapatnam, and Rajkot. Fuel station survey was conducted in these cities in year 2012. Secondary data sources get from databases maintained in vehicle undergoing the pollution under control tests during 1990 to 2012. Results showed that fuel efficiency was lower than other richest cities. The average age of cars and MTW were similar to China and lower than in high-income countries like Europe and United States of America.

Jayasekera (2015) conducted a research to calculate the VKT in Sri Lanka and develop a model to predict VKT factors in future years. Fuel station surveys used in 6:00 a.m. to 6: 00 p.m. Motor vehicles in whole Sri Lanka in 2012 were taken in this calculation. More than 500 questionnaires in fuel stations were collected. The results showed that most VKT were depended by motorcycles in petrol vehicles as 15.41 million kilometers and highest VKT in diesel vehicles were going to passenger vans. According to this study 505.192 million travel by using vans. Highest number of wagons used in western province. Motorcycles have the highest VKT, the second highest gone to three wheelers by calculating fuel growth factor of 2012. In this research vehicle factor were calculated to different vehicle and district wide in whole Sri Lanka.

In Malaysia, many people use private vehicles and as a result a higher number of crashes were reported (Shabadin et al., 2014). In this case VKT is important as a road safety

indicator. The objective of this research was to estimate Average Annual Kilometer Travelled (AAKT) and VKT in Malaysia and improve new method for AAKT and VKT. Odometer reading data was used to VKT calculation. New motor vehicle sales in Malaysia from 2009 to 2013 have been selected for the study. Odometer reading data were collected in the headquarters of Perodua, Proton and Toyota. Total number of samples collected was 521,134 data. Average kilometer car travelled has been found as 24,129 kilometer in 2013. Selagon was the highest average kilometer car travelled city with 28,375 kilometer and lowest city was Jonor with 1,6342 kilometers. Result showed that the average annual kilometer car travelled based on car brand proton had 22,048km AAKT. Toyota and Proton had 24,895 and 27,994 km AAKT. These factors are needed for better understanding of the increasing pattern. This method is considered more reliable with the number of samples being quite more representable.

Jung et al. (2017) estimated VKT and road emission in urban areas in Incheon City during 2013. Two different data collection methods were used; those were registered vehicle data, and traffic volume data. Road emission was estimated using traffic volume data. Registered vehicle data was based on AADT method and traffic volume data was collected covering 336 links in Incheon City. Based on registered vehicles, VKT was 6,149,468,108 veh-km/day and based on traffic volume VKT was 23,335,601 veh-km/day. Based in traffic volume, VKT was 2.11 times lesser in VKT based on registered vehicle. The result indicated that large trucks and middle trucks gave pulse value for different between traffic based on VKT and vehicles registered VKT in Incho city travelled than registered in other cities. Diesel trucks were emitted more air pollution gas to atmosphere. NOX percentage of 78%were emitted by diesel trucks. These results were given valuable data for air quality. Most truck emissions from registered vehicles were re-evaluated relative to the volume and speed of traffic using the VKT Method.

Improved methods of collecting travel data are needed for individual activities (Safi et al, 2017). An alternative to the traditional method is the collection of Global positioning system (GPS) data. The objective of this research was to conduct a travel survey using GPS - assisted data collection method to use further VKT estimation. In this research four GPS methods were used in New Zealand, which were Web-based data collection, method S-tracker method, H-tracker and ATLAS II. This survey was conducted during February to April in 2014. The quality and accuracy, the demographic attributes and frequency of reported trips in terms of the mode of travel were compared with these methods. Empirical comparison was used for comparing these methods. The results of this study showed that ATLAS II quality of the data collection was highest while S-tracker the lowest. ATLAS II had the highest ratio around 80% of compared with other three methods in reported to requested travel-days. As conclusion ATLAS II had the highest level of quality compared to the other three GPS methods. The S- tracker method had the lowest quality and H- tracker and the web-based methods had average quality level.

Kim et al. (2015) investigated mobile phone usage for annual survey conducted by Korea Transport Institute for collecting passenger car information like vehicle travel distance, oil consumption, maintenance cost, etc. In this study for collecting vehicle, operation, vehicle maintenance and personal information, a questionnaire survey consisting basic survey and trip diary survey was conducted both paper based and mobile phone based. When comparing the responses of two survey methods using t-tests, it was shown that statistical significant difference in all travel indicators. The average travel distances per person per day was 10.1 km according to the mobile-phone survey while the value obtained from paper based survey was 12.8 km. When the average number of passengers per day considered, the mobile phone survey gave approximately 20% more than that of paper based survey. The authors argued that mobile phone survey respondents have ability to record the travel diary directly real-time but paper based survey respondents need to recall the travel at the end of the day and record them. When

compared to paper based surveys, mobile phone surveys have advantages when considered convenience of respondents and the budgetary restraints; however, more research is needed to understand the differences in the responses in these two methods.

There is an issue in collecting accurate VKT data in local roads which is needed for highway agency for many business applications in the United States (Klatko et al., 2017). Currently the VKT estimates are based on the inadequate traffic counts in the local roads and resulted poor reliability of the estimates. Klatko et al. (2017) proposed clustering the local roads and then imputes traffic-volume data for segments within each cluster by applying spatial interpolation techniques and sparse traffic-volume data. Geographic Information System-enabled spatial interpolation algorithms, including Kriging, inverse distance weighting, natural neighbor, and trend techniques were proposed in this method. The method was validated with a sample of original AADT data set and this validation data set was used for comparing the predicted and actual daily VMT.

There were many different empirical approaches on VKT estimation for diffrent regions with limited traffic volume data. The household travel survey based method seems the most suitable for the developing countries as proposed by Gunathilake and Amarasingha (2020). However, the method was not validated so far. The validation of the method could be done comparing the estimated yearly VKT from the household travel survey with the VKT estimated from ADT data.

3. METHODS

Figure 1 illustrates the methods followed in this study.

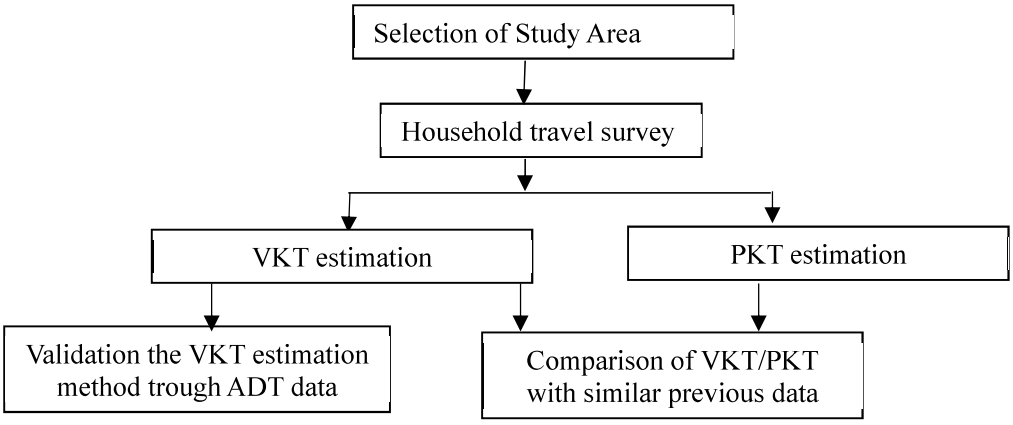

Figure 1. Flow Chart of the study

3.1 Study Area

The validation of household travel survey based VKT estimation was conducted at Uva Province of Sri Lanka. In the Sri Lanka, 93% of travels are on roads and streets. Road transportation in Sri Lanka consisted with highways, flyovers and A, B, C, D and E class roads/streets. Currently, Sri Lanka have 116,800 km road length according to latest records from the Road Development Authority (RDA). According to RDA data, road lengths based on the class of the road are 4,215.05 km for A-class, 7,994 for B-class, and 169.84 km for E-class roads. In Sri Lanka, at year 2020 around 8 million vehicles run on the roads (Department of

Motor Traffic, 2021). As shown in Table 1, vehicle population in Sri Lanka from 2015 to 2020 has been increased in each year. The majority of them are motorcycles followed by three-wheelers, cars, and vans.

Table 1. Vehicle population in Sri Lanka 2015-2020 (Department of Motor Traffic, 2021)

Type of vehicle	2015	2016	2017	2018	2019	2020
Car	672,502	717,674	756,856	873,632	875,864	894,871
Three wheelers	1,059,042	1,115,987	1,139,524	1,159,587	1,175,077	1,181,985
Motorcycles	3,359,501	3,699,630	4,044,010	4,383,773	4,668,074	4,803,344
Buses	101,419	104,104	107,435	110,392	112,005	112,450
Vans	365,001	391,888	408,630	425,561	439,020	447,630
Lorries	318,656	323,927	332,616	339,671	343,409	345,492
Land vehicle Tractors	342,381	352,666	361,487	368,947	374,643	377,573
Land vehicle Trailers	59,426	63,088	67,316	70,138	72,108	73,773
Total Vehicles	6,302,141	6,795,469	7,247,122	7,727,921	8,095,224	8,273,153

Also, the. Uva Province is fourth largest province around 8,500 square kilometers but second least population in Sri Lanka, which is around 1millon in year 2012. Badulla is the capital districts in Uva province. Eastern, Southern, Sabaragamuwa and Central provinces are bordered to Uva province. In Figure 2 shows study area, which consists of Badulla and Monaragala districts which are marked in red and green coloures. Uva province does not have expressways but consist with 1,147 km of A-class and 1,741 km B-class roads. In most parts of Uva province, infrastructure facilities do not in sufficient standard, and economic status is not in good level because of poor conductivity. Agriculture is the main economic activity in Uva Province. In Badulla district, the most of the people grow tea and vegetables. In Monaragala district, it is mostly paddy. Lot of outsiders are travelled to Uva province for recreation and religious activities. Most attractive places in Uva province are Ella, Haputhale, Dunhida fall, Katharagama, Muthiyaganaya etc. Many Uva province people do not travel outside the province for their day today activities as the geological situation discourage commute trips but agricultural good are commonly transported to other provinces.

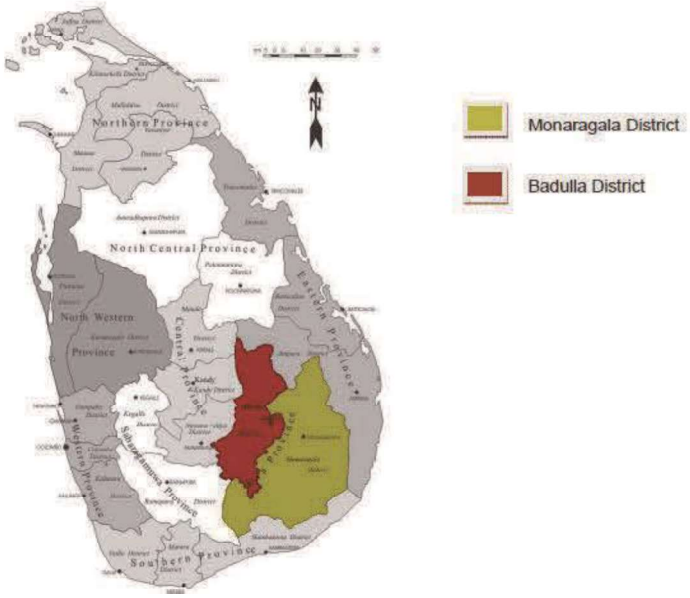

Figure 2. Study area in Sri Lanka map

3.2 Household Travel Survey

In household travel survey method, data on gender, age, economical factors, and living area were collected through a questionnaire form which was developed by Weerasekara and Amarasingha (2017). Trips including weekdays, weekends and holidays were separately collected throughout whole year using the questionnaire. Initially a pilot study was conducted distributing 30 questionnaires randomly in Uva province in online flat form because of country was locked down due to first wave of Covid-19 pandemic. The results of the pilot study was used to calculate the sample size of the study. The sample size of household survey was determined by using Equation-1 (Weerasekara and Amarasingha, 2017).

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

The coefficient of variation was taken from the pilot study results and the sample size obtained was 450 with 95% of level of accuracy. The drawback of online questionnaire has the limitation in responses because questionnaire is answered only those who have the internet facility and sufficient computer literacy. Therefore, the level of accuracy of sample size was back calculated by data collected by random 450 respondents in Uva province. Equation 1 was used to back calculate the level of accuracy.

The data collection was done during May 2020 after the reopening the country after first wave of Covid-19 pandemic. The impact of the lockdown in Uva province is minimum because Covid-19 patients are not reported during that time in the Province and Sri Lankan government is continuously allowed all the agricultural activities beside the Covid-19 Pandemic. As most of people are involved in agricultural activities in the Province, it may not be much lower travels in the province during the time of data collection. Also, the respondents are informed that they need to give the information before Covid-19 pandemic.

3.3 VKT Estimation

The Household and ADT method were selected to estimate the VKT for this study. Once the data is collected, VKT was estimated for each traveler and multiplied by weighed factors considering the proportion of the different socio-economic groups as shown in Equations 2 and 3 (Weerasekara and Amarasingha, 2017).

VKT= Number of vehicles* Distance travelled*Weighed factor (2)

Weighed factor = Population in category/ Total population (3)

These were derived considering socio-economic information of whole Uva province population, to obtain the total VKT value avoiding the sampling errors. Weighed VKT was calculated considering each factor such as traveler's gender, age, employment status, and living area.

3.4 PKT Estimation

Further to VKT estimates, the PKTs were also estimated considering the number of occupants reported in each vehicles. Additionally, the vehicle characteristics of each of the mode is also estimated by using data collected through questionnaires forms.

3.5 Comparison of VKT/PKT Estimations

The VKT/PKT of the Uva province has not been previously estimated at the authors' knowledge. Therefore, VKT estimates of Uva province were compared with previous VKT/PKT estimates available in southern province, which is located very close proximity to Uva province. However, VKT data of Southern Province were collected during 2017 but the same questionnaires form was used to collect data. The comparisons of VKT and PKT values between different variables were carried out using t-tests. In the t test, null hypothesis is that the means of VKT/PKT of two provinces are the same. The alternative hypothesis is that the means are not equal. If the population distributions two provinces can be assumed to have the same variance and, therefore, the same standard deviation of two provinces can be pooled together, each weighted by the number of cases in each sample as shown in Equation 4;

$$S_p^2 = \frac{(n_1-1)S_1^2+(n_2-1)S_2^2}{n_1+n_2-2} \quad (4)$$

where s_1 and s_2 are the standard deviations of the two samples and n_1 and n_2 are the sizes of the two samples (Gaur and Gaur, 2007). Equation for comparing the means of two populations using pooled variance is given in Equation 5;

$$t = \frac{\bar{x}_1-\bar{x}_2-\Delta}{\sqrt{S_p^2\left(\frac{1}{n_1}+\frac{1}{n_2}\right)}} \quad (5)$$

where $\bar{x}_1$ and $\bar{x}_2$ are the means of the two samples, Δ is the hypothesized difference between the population means (0 if testing for equal means), S_p^2 is the pooled variance, and n_1 and n_2 are the sizes of the two samples (Gaur and Gaur, 2007). Then the t- Statistics table value is larger than the absolute value of the computed t-value, the null hypothesis of equal population means cannot be rejected.

3.6 Validation of VKT Estimation Method

The estimated VKTs using the household travel survey were validated with the VKT estimates from ADT data available. The segment length of Uva Province roads were multiplied with the ADT of each of the road segment to obtain VKT values. ADT data collected in Uva province by RDA were obtained for this study. The VKT value was then multiplied by 365 to get yearly VKT. All the VKT in selected roads were cumulated and also selected roads lengths were cumulated (Jung, et al., 2017). Then total VKT was divided by total selected roads lengths. After that it was multiplied by total road length in Uva province. Finally, the total VKT was divided by total vehicles in Uva province to get VKT per vehicle. VKT were multiplied by passenger car equivalent factor to compare household survey and ADT survey. The comparison was done using t-test.

4. RESULTS AND DISCUSSION

4.1 VKT Estimates

The estimated VKT values are shown in Table 2 and differences of VKT estimates between Uva province in 2020 and Southern province in 2017 are also presented in the Table 2. The

significant values of t-tests for the differences VKT in two provinces are presented last column of Table-2. If the significant value is less than or equal to 0.05, reject the null hypothesis of means of two sample are equal in favor of the alternative hypothesis of means are not equal. If the significant value is greater than, the null hypothesis can not be rejected that implies the means of the two populations are statistically different. The differences in travel pattern in two provinces are discussed in following sections.

VKT of male was significantly higher in Southern province in 2017 compared to that of Uva province in 2020. This may because mostly due to the males in Southern province travelled day today works than that of Uva province. Another reason may be the lockdown imposed by first wave of COVID-19 pandemic. Employed person in Uva province in 2020 travel statically more distances than Southern province employed person in 2017 travel. That may be because most of Uva province people employed in outside of the province. VKT of Uva province rural person had statistically significant lower VKT compared to that of Sothern province person. This may be due to VKT is shorter in rural area or vehicle ownership ratio is lower in rural area. According to t-test results, VKT of Uva province unemployed persons and Sothern province unemployed persons did not have a significantly difference. Also, VKT of Uva province in age 15-24 years, 45-54 years 55-64 categories, income less than 25,000 LKR and in between LKR 75,000-100,000, and urban people did not show statically significant different compared to that of Southern province.

Table 2. Comparison of weighted VKT values for Uva and Southern provinces

Characteristics	Category	VKT per person (km)		Significant value for t-test
		Uva Province (year 2020)	Southern Province (year 2017)	
Gender	Male	2,305	4,912	0.001
	Female	1,258	2,327	0.001
Age	15-24	614	1,229	0.095
	25-34	899	2,540	0.000
	35-44	736	1,575	0.011
	45-54	713	1,405	0.222
	55-64	560	490	0.550
	65+	39	-	-
Employment status	Employed	2,646	5,008	0.000
	Unemployed	917	2231	0.134
Area	Rural	3,310	6,500	0.001
	Urban	251	738	0.099
Income (SLR in '000)	25	3,297	3,744	0.478
	25-50	5,111	7,736	0.004
	50- 75	6,649	10,812	0.032
	75 - 100	7,321	11,532	0.130
	100+	10,057	4,123	0.034

4.2 PKT Estimates

PKT is another very important parameter for transportation planning. PKT was estimated by multiplying the VKT by number of people in the vehicle and Table 3 shows the PKT values for Uva Province in 2020 and Southern Province in 2017. PKT values of males was significantly higher in Southern province in 2017 compared that of Uva province in 2020. This may because in Southern province people travelled more for their day today works to Uva province people. Another reason may be the lockdown imposed by first wave of COVID-19 pandemics during

2020. PKT values of females was significantly higher in Uva province in 2020 compared to that of Southern province in 2017. People age between 15 and 24 years travelled more in Uva province in 2020 that of Southern province in 2017. PKT values in other age groups were not statistically different between Uva province in 2020 and Southern province in 2017. Both employment and unemployment people in Uva province in 2020 travelled more compared to that of people in Southern province in 2017.

Table 3. Comparison of PKT values for Uva and Southern provinces

Characteristics	Category	PKT per person (km)		Significant value for t-test
		Uva Province (year 2020)	Southern Province (year 2017)	
Gender	Male	12,269	21,053	0.023
	Female	19,769	7,715	0.005
Age	15-24	10,172	5,036	0.000
	25-34	6,884	9,276	0.258
	35-44	6,012	8,018	0.068
	45-54	5,382	4,611	0.751
	55-64	3,286	1,828	0.655
	65+	303	-	-
Employment status	Employed	19,383	14,194	0.015
	Unemployed	12,656	6,771	0.000
Area	Rural	29,889	24,915	0.483
	Urban	2,149	3,853	0.535
Income	25	36,963	13,209	0.000
	25-50	38,231	35,224	0.917
	50- 75	31,411	5,870	0.067
	75 - 100	20,799	46,408	0.062
	100+	16,518	17,435	0.501

4.3 VKT by Vehicle Type

The travel behavior of people is significantly different with respect to the mode they chose to satisfy their transportation needs. In this study, travel on six categories of modes: car, vans, jeeps, motorcycles, three-wheelers and bus were investigated. Figure 3 shows VKT per person in each mode of vehicles with respect to gender.

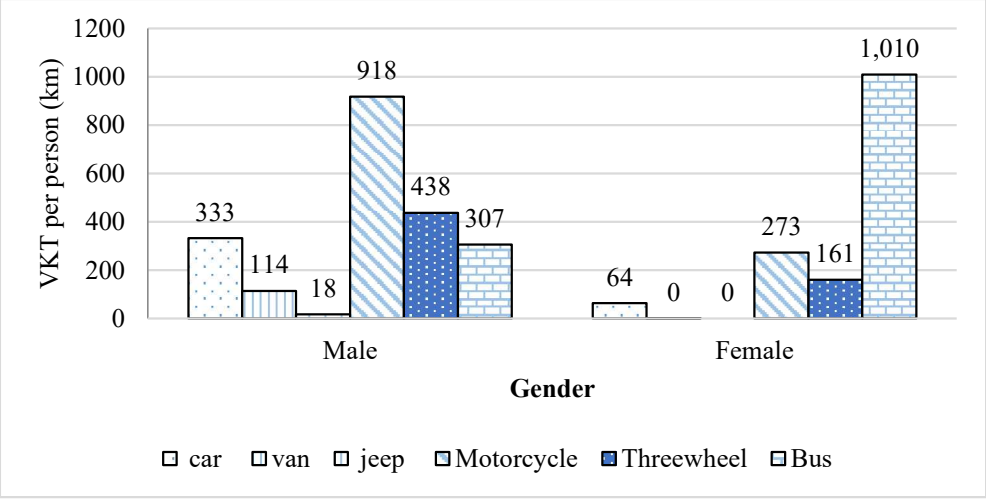

Figure 3. VKT of different modes by Gender during 2020 in Uva province Sri Lanka

Females mostly travelled by buses; this may be due to the lack of vehicle ownership among females. Most males travelled by motorcycles; this may be because all people preferred to use motorcycle for their day today works as a motorcycle is cost-effective. Also, female travelers did not travel by jeeps or vans, this may because those vehicles are not popular among females.

Figure 4 shows VKT by mode of vehicle with respect to age category. The age category ranges between 15-24 years, preferred bus as their transport mode. The underlying reason may be the financial dependability of the age category. Therefore, they are not able to own a vehicle. Most travelers between 25 to 54 years were travelled by motorcycles and most people in Uva province used motorcycle for their daily works. Older people (55-69 age category) more likely to stay at homes as most of them are retired persons. Therefore, their transportation need is lesser values as shown in Figure 4.

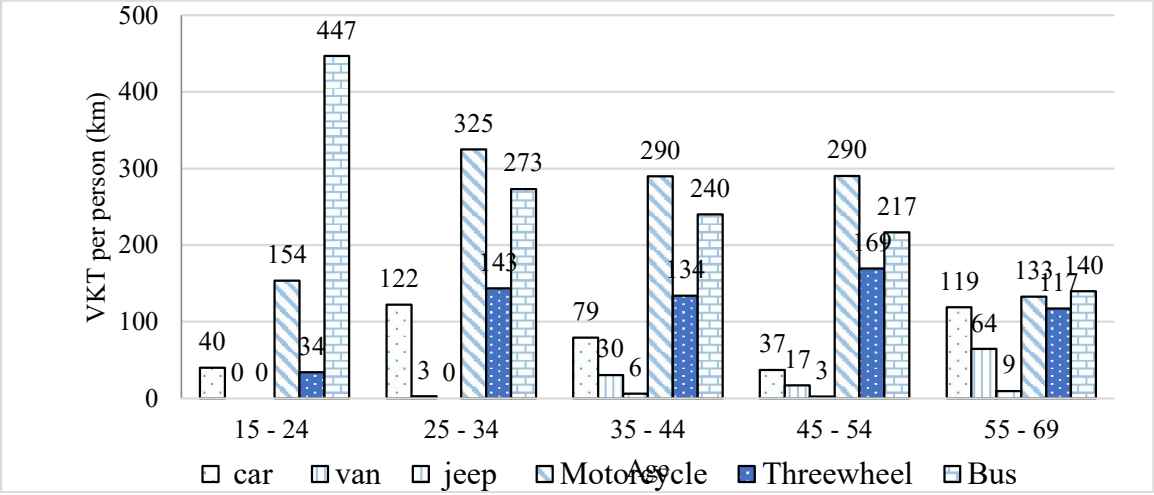

Figure 4. VKT of different modes by age during 2020 in Uva province Sri Lanka

Figure 5 shows VKT by each mode of vehicle based on urban/rural nature. In rural, most people travelled by motorcycle for short distances and by bus for longer trips. People who live in urban area, travelled lesser kilometers in all vehicle types than those of rural area because their destinations such as schools, hospitals and supermarket are located within the urban area.

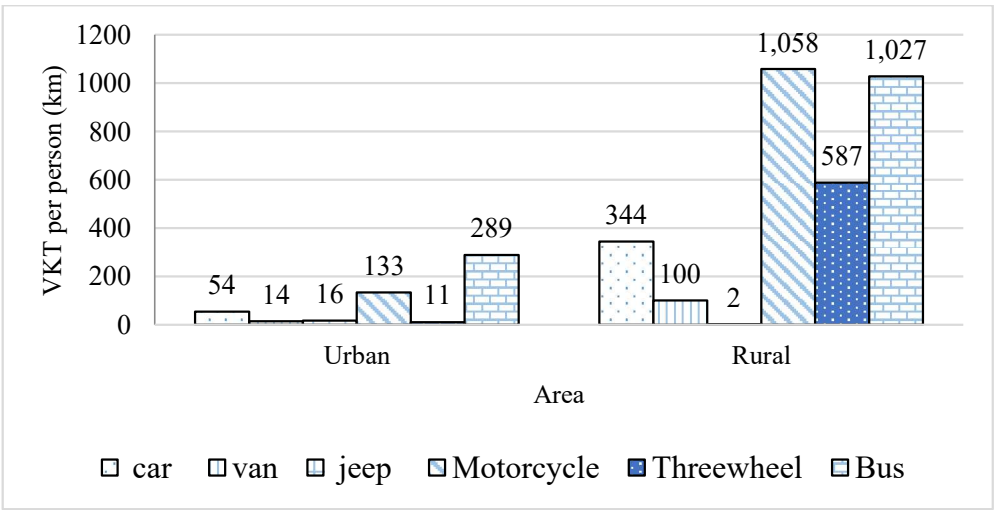

Figure 5. VKT of different modes by urban/rural nature during 2020 in Uva province Sri Lanka

Employed personnel mostly travelled by motorcycles and unemployed personnel travelled using public transport according to Figure 6. Compare to other vehicles, motorcycle travelled vehicle kilometers was high because of employed people are financially capable of purchasing motorcycles to satisfy their travelling requirements. It is understood that most of the times van used for special trips only and jeep were used by a limited number of peoples in Uva province.

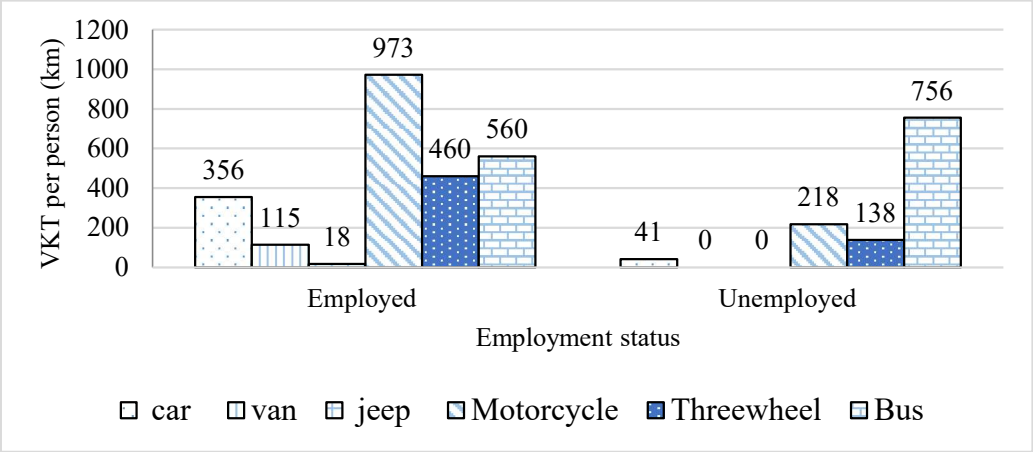

Figure 6. VKT of different modes by employment status during 2020 in Uva province Sri Lanka

In this study the unit of analysis was considered as the 'traveler' but for the comparison purposes if VKT per person per vehicle was taken, that would be provided more information related to travel distances. For example, 64 km car travel by females means average car distance travel by females during the year. In reality, car owned females drive more than the value and others will have 0 car-travel distance. Therefore, in order to get more realistic picture, the vehicle ownership details should be taken into account. However, vehicle ownership details in the different socio-demographic categories are not available for Uva province population but those information could be collected through the questionnaire for the sample.

4.4 Validation of Household Travel Survey Based VKT

Estimated VKT in ADT method was compared with VKT in household survey method. Figure 7 shows estimates of VKT per vehicle using ADT data and household survey method. VKT estimates using ADT data was not significantly differ to the VKT estimates of household survey method (P=0.342). When considered VKT values, smaller variations in numbers this may be because travel restrictions during 2020 due to Covid-19 pandemic as ADT estimates obtained from RDA based on some vehicle counts taken before lockdown. Though travel pattern of Uva people had not changed, the visitors from other provinces did not travel in Uva province. As VKT estimates are not significantly different to VKT estimates of the theoretical method, it is proved that the household travel surveys can be used for VKT estimation as an alternative methods for developing countries. Household survey method is cost effective method to estimate both VKT and PKT data together with information related mode choice. Further, it needs lesser funding, resources and comparatively lesser time duration to estimate to the VKT estimates using yearlong traffic flow data. Household travel surveys can be conducted annually in regional level and can be aggregated at the national level. In developing countries like Sri Lanka, some government officers have been assigned to each village and their help could be

obtained to conduct the annual questionnaire surveys which would be more efficient and effective. Therefore, the proposed method can be implemented without initial funding and using the proposed data collection more accurate policy decisions could be made.

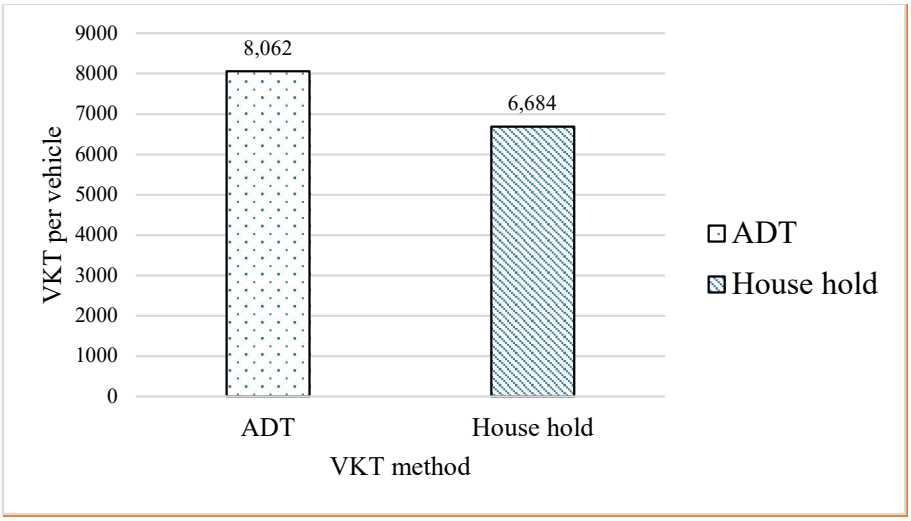

Figure 7. Comparison of VKT per vehicle estimates from ADT data and household travel survey

5. CONCLUSIONS

This research study found out the variations of VKT, PKT, and VKT by type of vehicle with respect to demographic information such as age, gender, per capita income for each household residence, employment status, and resident area. In this research study, kilometers travelled by each traveler during a period of one year was estimated in Uva province. One of the major findings of this study was the influence from gender as one of the key factors which depended on the distance travelled by each person. Males travelled 2,305 km per person in Uva Province when compared that of females (1,258km per person). But PKT of females was 19,769 km per person when compared to male (12,269 km per person) travelers. The main mode of travel used by males was motor bicycles and females was public transport. It was identified that age category 15-24, has travelled more than 10,000 km per person which is very high compared to other age categories. This was mainly due to the trips with destinations to the office, private places, shops, school etc. by their own vehicles. Motorcycle was the most preferred mode of transport among the people participated for this research study. Employed personnel usually preferred to use motorcycles when compared with other modes of transport and they travel more than 9,000 km per person when compared with unemployed travelers according this study. When corresponding to people live in residential areas, they like to use private vehicles due to ease of access within the city limits. When analyzing the data obtained, travelers from rural areas were using public transport and motorcycles equally. This is mainly due to the majority of the people were located in rural areas and essential needs and services were placed within the city limits.

One can argue that household survey may not much effective because many outsiders would travel in the study area and VKT/PKT not accounted the outsiders travelled in the study area. Therefore, VKT estimates of household survey was compared with VKT estimation of using ADT data. The results showed that VKT estimates using ADT data was not significantly

different with household survey method. Therefore, as suggested by Gunathilake and Amarasingha (2020) this method can be effectively used for estimating VKT for developing countries as a cost effective method. In this method, many other important information can also be collected as side benefits.

There could be some errors in household travel survey due to misinformation provided by the participants in the surveys. A larger sample size will help to reduce the effects from this error. Due to COVID-19 pandemic situation, vehicle counts became impossible to collect but recorded ADT data were used which was collected from RDA. Some error was occurred by that case. To minimize errors which occurred in ADT method, it is recommended to get ADT count manually on roads in that area. And also getting traffic data in several locations in each road would be minimize the error.

Estimation of VKT using household travel survey has substantial benefits to develop infrastructure, improve road safety policies, traffic and transportation with utilized local planning, and estimate emissions in developing countries. The future traffic contingencies based on traffic volume with the growth of traffic around Uva province can be utilized based on the experimental data obtained and analyzed as a requirement of this research. VKT estimation in Sri Lanka is became necessary for the country because only few studies have conducted and many decisions for the road sector improvement can be logically taken based on VKT data. Total distance travelled in Uva province roads can be used to find type of vehicle usage by fuel type and how they are using on roads, environmental effects because of vehicle usgae, and funds spend on roads for improvements. VKT data can be used as an indicator of economy growth of the area and changes of infrastructure in Uva province.

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