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Original Paper

Effects of Driver and Vehicle Characteristics on Annual Vehicle Kilometers of Travel in Jordan

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Abstract

This paper investigates the effects of the driver and vehicle characteristics on the vehicle kilometers of travel (VKT) in Jordan. The study used a survey form based on the multiple-choice type of questions that was distributed to a total of 1265 Drivers randomly selected for different vehicle types and from all major regions in the country. The study has covered the major driver characteristics (gender, age, education, occupation, family income, family size, and family auto ownership) and vehicle characteristics (type, age, engine size, registration, and use). The different categories of all driver and vehicle factors had significantly different values of VKT. The highest VKT values were associated with males, age of 40-49 years old, education of less than high school, occupation of a driver, monthly family income of less than JD 250 (USD 352.5), family size of more than or equal to eight, no family auto ownership, trucks and buses, new vehicles (<5 years old), high engine size (>4000 cc), and transit and cargo vehicles. No significant differences were found between different regions in the country, and the total VKT for Jordan based on different vehicle types and vehicle registration statistics in 2011 was estimated to be around 24 billion kilometers per year.

Keywords: VMT, VKT, Vehicle, Kilometers, Travel, Driver.

1. Introduction

Vehicle Miles of Travel (VMT) estimates are important for several uses including transportation plans and policies establishments, energy use and air pollution estimates, funds and resources allocations, traffic impacts assessments, and as accident exposure measures. US traffic fatalities in 2012 showed an increase of 5.3 % as compared to 2011, which was accompanied by 0.3 % increase in VMT (NCSA, 2013) [18].The FHWA has estimated the annual VMT for USA during 2011 as 2.95×10^{12} (FHWA, 2012) [9]. It also provided these estimates by state, area type (rural or urban) and road functional classifications (interstates, other freeways and expressways, other principal arterials, minor arterials, major collectors, minor collectors and locals). So VMT estimates are needed on the Federal level, State level, and highway functional class level to be more useful for different applications. Jordan and some other countries replace the unit "mile" by "kilometer", so VMT becomes vehicle kilometers of travel (VKT). Currently there are no accurate estimates for VKT in Jordan and this study comes as the first national research effort in this area based on a questionnaire that was distributed to drivers of different vehicle types covering all vehicle categories according to registration records at the traffic police department, such that the results can be expanded to estimate the country VKT.

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This study gave the opportunity to investigate the driver and vehicle characteristics on VKT in Jordan. Driver characteristics included driver gender, age, education, occupation, monthly family income, family size, and family auto ownership. Vehicle characteristics included vehicle type, age, engine size, registration, and use. It is believed that the results of this research will lead to further research studies to better understand all VKT influencing factors and provide more accurate VKT estimates for the whole country as well as by the region, city, road class, and vehicle type.

2. Literature Review

Since decades Governments have adopted policies to reduce pollution and energy consumption which are believed to be directly dependent on VMT values. The MOBILE model is an example for estimating air pollutants for mobile sources based on variables including VMT by vehicle type and roadway functional classification (Smith and Park, 2006) [23]. AASHTO (2009) has adopted a strategy to reduce emissions in the US through better cars, better fuels, system optimization, and smarter travel by reduction of growth in VMT and increasing public transit ridership [1]. Toth (2007) has investigated the potential of influencing land use patterns to restrain growth in VMT [25].

Several methods have been adopted to estimate VMT values in different levels and for different applications. Teng and Wang (2011) have reported that VMT values may be estimated for different highway classes based on regular automatic traffic counts or ITS systems such as detectors and cameras [24]. Fugitt and Shafizadeh (2010) have modeled VMT as a function of the surrounding land use diversity [12]. Rooney and Srinivasan (2008) used the U.S. Census data to predict household VMT based on variables like % of household workers using public transit and commute time to work [21]. Fricker and Kumapley (2002) used the cross-classification models to estimate VMT based on licensed driver and household travel characteristics considering the driver sex and age [11].

Morey et.al (2004) introduced a procedure for estimating VMT on unpaved roads using GIS and statistical models [17]. Zhang and He (2013) suggested that VMT estimation on different road classes using GPS-based surveys are feasible and cost-effective [28]. On the other hand, Davis and Donath (2013) have introduced a method for aggregating VMT within predetermined geographic areas utilizing the cellular assignment that were believed to be better than the GPS based methods in preserving the user privacy [7].

It is difficult to make traffic counts at all local roads as they form the majority in road networks. Frawley (2007) has used the random traffic count site selection process at local roads for estimating their VMT and this was approved by the FHWA [10]. While Byrne et.al (2008) have developed models for estimating VMT on local roads based on population density and road surface type [4].

Since over three decades, the FHWA has used the random selection and sampling of highway links to predict VMT by area type, facility type, and traffic volume (Hoang and Poteat, 1980) [13]. Ferlis and Bowman (1981) have listed 3 major sources of uncertainty in estimating VMT including measurement error, temporal variability, and spatial variability [8].

Several studies have been conducted to identify the influencing factors on VMT. Rentziou (2012) has modeled the influence of fuel tax, socioeconomic, demographic, and other factors on VMT in the US [20]. Wang and Chen (2012) have investigated the effect of fuel price on VMT by analyzing a sample from the 2009 US National Household Travel Survey and found that lower income groups show less fuel price elasticity than higher income groups [26]. However, McMullen and Eckstein (2012) found no significant causal relationship between economic activity and VMT [16].

Salon et.al (2013) have quantified the effects of transport and land use policies on VMT [22]. The transport policies included transit improvements, road pricing, and programs that change travel choices, while land use polices included the residential density and land use mix. Clower et.al (2011) have conducted a survey on residents of selected US areas with transit-oriented development projects and found that these projects have decreased VMT by around 15 % [5].

Many studies have focused on the roles of household, driver, and vehicle characteristics on VMT. Akar and Guldmann (2012) have investigated the two-vehicle households and found that VMT is directly proportional with the household income; number of adults, workers, children, and vehicles; having the option to telecommute; and owning SUVs, pickup trucks, vans, or hybrid vehicles [2]. On the other hand, VMT was found inversely proportional with gasoline cost; population density; and if the driver of a vehicle was a female, older, unemployed, or did not hold a BSc degree.

Wang (2007) utilized the motor vehicle registration information to estimate VMT by vehicle type [27]. Pickrell et.al (2012) built a model for the FHWA that forecasts VMT by functional classification, vehicle type (light-duty, SU trucks, combination trucks, and buses), vehicle age and model year [19]. Lave (1994) reported that VMT estimates based on the 1990 NPTS were not accurate due to the oversampling of new vehicles which were usually driven 2-3 times the older ones [15]. Caltrans (2008) reported that VMT is affected by socioeconomic factors such as fuel cost, income, population, and the number of vehicles per person [6]. Benekohal and Girianna (2002) have criticized the current IDOT methodology for estimating truck VMT and proposed a more accurate procedure for its estimation for different truck categories on different road functional classes [3].

3. Data Collection and Reduction

The study was conducted to estimate the VKT for Jordan based on the multiple-choice type of questions that was distributed to a total of 1265 drivers randomly selected for different vehicle types and from all major cities in the country. The chosen vehicles have covered all vehicle types according to registration records at the traffic police department. The results for different vehicle types were then expanded according to their corresponding populations to estimate the country VKT.

Data collection was conducted by trained traffic technicians during the year 2011, through interviewing drivers and investigating their vehicle oil change records. The VKT values were estimated for each vehicle based on its oil change records and information taken from their drivers regarding the average number of days and driven kilometers between vehicle oil changes all over the last year.

A total of 1265 drivers were interviewed from all major regions in the country (north, middle and south). The survey form was designed to cover the main vehicle and driver characteristics that are believed to affect VKT values. Driver characteristics included driver gender (male and female), age (18-29, 30-39, 40-49, 50-59, ≥ 60 years), education (< high school, high school, BSc, and graduate (MSc/PhD)), occupation (public, private, driver, retired, unemployed, and other), monthly family income (< 250, 251-500, 501-750, > JD 750), family size (1, 2, 3, 4, 5, 6, 7, ≥ 8), and family auto ownership (0, 1, 2, ≥ 3). Vehicle characteristics included vehicle type (PC, minibus, Bus, SU truck, large truck, agriculture vehicle, motorcycle, special purpose vehicle, construction vehicle, and dual purpose vehicle), age (≤ 5, 6-10, 11-15, 16-20, > 20 years), engine size (≤ 1000, 1001-1500, 1501-2000, 2001-2500, 2501-3000, 3001-4000, > 4000 cc), registration (public, private, transit/cargo), and use (PC, transit, cargo, dual purpose, and other).

4. Analysis and Results

Based on a total of 1265 observations considering all driver and vehicle categories combined, the average VKT was 24059 km/year with a range from 365 to 96360 km/year and a standard deviation of 20069 km/h. The median VKT was 16425 km/year and the modal VKT was 18250 km/year as can be seen from

Table 1. No significant differences were found between different regions in the country as shown from Table 2.

Table 1. Summary of Basic Statistics

Statistic	Value
Number of Observations	1265
Mean (km/year)	24058.84
Median (km/year)	16425
Mode (km/year)	18250
Standard Deviation (km/year)	20069.126
Range (km/year)	95995
Minimum (km/year)	365
Maximum (km/year)	96360

Table 2. Annual Vehicle Kilometers of Travel vs. Country Regions

Region	Mean	N	Std. Deviation
North	25438.56	226	20609.887
Middle	23791.88	906	20219.885
South	23532.89	133	18047.327
Total	24058.84	1265	20069.126

F-Value = 0.66, $P < 0.517$

4.1 Effect of Driver Gender

Driving in Jordan is dominated by males so only 58 females were covered among the interviewed drivers. Table 3 shows that male drivers had higher VKT values (24614 km/year) than female drivers (12511 km/year), with a statistical significant difference at 95 % confidence (F-value = 20.4, $P < 0.000$). This is due to the fact that Jordanian males have more involvement in outdoor activities than females. Also, most females do not usually drive for long distances outside urban areas due to the social norms in the country.

Table 3. Annual Vehicle Kilometers of Travel vs. Driver Gender

Driver Gender	Mean	N	Std. Deviation
Male	24613.76	1207	20304.978
Female	12510.69	58	8132.901
Total	24058.84	1265	20069.126

F-Value = 20.4, $P < 0.000$

4.2 Effect of Driver Age

Table 4 shows a statistically significant difference in VKT between different age groups at 95 % confidence (F-value = 4.8, $P < 0.001$). The highest VKT were travelled by the age group of 40-49 years old (VKT=26911 km/year) because large proportions of transit and cargo drivers were among this age group. On the other hand, the lowest VKT were travelled by the age group of more than or equal to 60 years old (VKT=14732 km/year), because 60 years old is the retirement age in Jordan. Other age groups had VKT values that were close to the overall average for the whole study sample.

Table 4. Annual Vehicle Kilometers of Travel vs. Driver Age

Driver Age (years)	Mean	N	Std. Deviation
18-29	24329.09	258	19163.123
30-39	23144.28	467	19152.176
40-49	26911.41	348	21915.077
50-59	22700.48	145	20161.239
≥ 60	14732.02	47	15470.187
Total	24058.84	1265	20069.126

F-Value = 4.8, $P < 0.001$

4.3 Effect of Driver Education

Table 5 shows a statistically significant difference in VKT between different education groups at 95 % confidence (F-value = 14.0, $P < 0.000$). The highest VKT were travelled by drivers with the least education level of less than high school (VKT=27409 km/year) because large proportions of transit and cargo drivers were among this education category. As education level increases, the VKT value decreases with the lowest VKT for drivers with graduate education level (VKT=16762 km/year). This is due to the fact that as education level increases, drivers have more chances of getting higher paying jobs, which give better opportunities of living closer to work places, and reduce the need for other part time jobs.

Table 5. Annual Vehicle Kilometers of Travel vs. Driver Education

Education	Mean	N	Std. Deviation
< High School	27408.57	424	22472.528
High School	26252.80	416	21356.040
Diploma (2 years)	21974.72	127	18553.117
BSc	17193.58	246	11839.650
Graduate (MSc/Phd)	16761.92	52	11561.274
Total	24058.84	1265	20069.126

F-Value = 14.0, $P < 0.000$

4.4 Effect of Driver Occupation

Table 6 shows a statistically significant difference in VKT between different occupation categories at 95 % confidence (F-value = 18.4, $P < 0.000$). The highest VKT were travelled by drivers who work as drivers and drive a taxi, service car, bus, or truck for living (VKT = 33614 km/year). On the other hand, the lowest VKT were travelled by the retired drivers (VKT=17139 km/year) and the unemployed drivers (VKT=17423 km/year). It was noticed that drivers with private occupations had higher VKT than drivers with public occupations.

Table 6. Annual Vehicle Kilometers of Travel vs. Driver Occupation

Occupation	Mean	N	Std. Deviation
Public	20146.48	240	17374.307
Private	24957.87	503	20205.861
Driver	33613.77	227	23738.526
Retired	17139.30	93	14648.314
Unemployed	17422.67	15	13567.193
Other	19036.60	187	16012.890
Total	24058.84	1265	20069.126

F-Value = 18.4, P < 0.000

4.5 Effect of Driver Family Income

Table 7 shows a statistically significant difference in VKT between different driver family income categories at 95 % confidence (F-value = 14.0, P < 0.000). The highest VKT were travelled by drivers with the least family income of less than JD 250 (VKT=25636 km/year) because large proportions of transit and cargo drivers were among this driver family income category. As driver family income increases, the VKT value decreases. This is because higher family income, gives better opportunity of living closer to work place, and reduces the need for other part time jobs.

Table 7. Annual Vehicle Kilometers of Travel vs. Driver Family Income

Monthly Income	Mean	N	Std. Deviation
< 250 JD*	25636.12	178	20434.993
251-500 JD	25112.20	727	21075.506
501-750 JD	23240.40	235	19064.370
> 750 JD	17225.08	125	12833.794
Total	24058.84	1265	20069.126

*1 JD = 1.41 USD F-Value = 6.1, P < 0.000

4.6 Effect of Driver Family Size

Table 8 shows a statistically significant difference in VKT between different driver family size categories at 95 % confidence (F-value = 3.7, P < 0.001). The highest VKT were travelled by the drivers from families with 8 persons or more (VKT = 28341 km/year) because large proportions of transit and cargo drivers were among this driver family size category. On the other hand, the lowest VKT were travelled by single drivers (VKT= 17111 km/year) who have more chances of being unemployed or do not need much traveling as their shopping and social travel needs are limited.

Table 8. Annual Vehicle Kilometers of Travel vs. Driver Family Size

Family Size	Mean	N	Std. Deviation
1	17111.55	42	14431.484
2	20616.97	66	18719.718
3	23168.28	99	19562.423
4	23515.43	209	19593.139
5	21462.96	228	18537.423
6	23223.99	212	20211.455
7	26877.46	179	21539.403
≥ 8	28341.46	230	21246.704
Total	24058.84	1265	20069.126

F-Value = 3.7, P < 0.000

4.7 Effect of Driver Family Auto Ownership

Table 9 shows a statistically significant difference in VKT between different driver auto ownership categories at 95 % confidence (F-value = 22.4, P < 0.000). The highest VKT were travelled by drivers without family auto ownership (VKT = 38603 km/year) because they most likely work as drivers and drive a taxi, service car, bus, or truck for living as explained in section (4.4) before. As driver family auto ownership increases, the VKT value decreases, because the family traveling needs are distributed among different family vehicles.

Table 9. Annual Vehicle Kilometers of Travel vs. Driver Family Auto Ownership

Family Cars	Mean	N	Std. Deviation
0	38603.31	80	23702.438
1	24394.10	875	20276.480
2	20691.41	241	17489.837
≥ 3	14705.80	69	9533.687
Total	24058.84	1265	20069.126

F-Value = 22.4, P < 0.000

4.8 Effect of Vehicle Type

Table 10 shows a statistically significant difference in VKT between different vehicle type categories at 95 % confidence (F-value = 94.4, P < 0.000). The highest VKT values were for Busses and Trucks. The large trucks, minibuses, busses, and SU trucks had VKT values of 53332, 52757, 51042, and 36019 km/year respectively. On the other hand, the lowest VKT were for agriculture vehicles (VKT = 7665 km/year) and construction vehicles (VKT = 10067 km/year). Part of the remaining vehicle types had VKT values that were below the overall study average like passenger cars (VKT = 16710 km/year) and motorcycles (VKT = 13359 km/year), while other vehicle types had VKT values that were above the overall study average like dual purpose vehicles (VKT = 28700 km/year) and special purpose vehicles (VKT = 27893 km/year). The traffic fleet in Jordan (Jordan Traffic Institute, 2011) is distributed into 1.8 % of busses, 13.5 % of trucks, 71 % of passenger cars, and 13.7 % of other vehicle types [14].

Table 10. Annual Vehicle Kilometers of Travel vs. Vehicle Type

Vehicle Type	Mean	N	Std. Deviation
PC	16709.70	700	11722.644
Minibus	52757.10	50	18423.955
Bus	51041.60	50	18654.519
SU Truck	36019.21	145	21973.835
Large Truck	53332.12	52	22178.852
Agriculture Vehicle	7665.00	30	7893.830
Motorcycle	13359.00	35	6457.631
Special Purpose Vehicle	27893.30	50	23162.711
Construction Vehicle	10066.70	50	4844.007
Dual Purpose	28700.34	103	21822.329
Total	24058.84	1265	20069.126

F-Value = 94.4 , P < 0.000

4.9 Effect of Vehicle Age

Table 11 shows a statistically significant difference in VKT between different vehicle age categories at 95 % confidence (F-value = 15.9, P < 0.000). The highest VKT value was for vehicles with 5 years of age or less (VKT = 31972 km/year) because large proportions of transit vehicles are new due to government policies in regulating this sector. As vehicle age increases, the VKT value decreases, because drivers become less dependent on their vehicles and try to avoid using them for long distances.

The traffic fleet in Jordan (Jordan Traffic Institute, 2011) is distributed into 16.3 % of vehicles that are 5 years old or less, 15.8 % of vehicles that are 6-10 years old, 25.3 % of vehicles that are 11-15 years old, 17.5 % of vehicles that are 16-20 years old, and 25.1 % of vehicles that are more than 20 years old.

Table 11. Annual Vehicle Kilometers of Travel vs. Vehicle Age

Vehicle Age (Years)	Mean	N	Std. Deviation
≤ 5	31971.66	187	23376.048
6-10	27688.53	234	21460.146
11-15	22059.24	408	18119.174
16-20	22822.26	243	19537.112
> 20	17775.31	193	16097.428
Total	24058.84	1265	20069.126

F-Value = 15.9, P < 0.000

4.10 Effect of Vehicle Engine Size

Table 12 shows a statistically significant difference in VKT between different vehicle engine size categories at 95 % confidence (F-value = 58.8, P < 0.000). The lowest VKT value was for vehicles with engine sizes of 1000 cc or less (VKT = 13392 km/year) and as vehicle engine size increases, the VKT value increases, reaching the highest VKT values for vehicles with engine sizes of > 4000 cc (VKT = 39992 km/year) because most of these vehicles are used for transit and cargo delivery.

Table 12. Annual Vehicle Kilometers of Travel vs. Vehicle Engine Size

Engine Size (cc)	Mean	N	Std. Deviation
≤1000	13392.02	42	6562.819
1001-1500	16584.24	408	12090.073
1501-2000	17385.14	249	13313.626
2001-2500	21441.52	82	18552.809
2501-3000	29344.96	141	21136.975
3001-4000	30594.38	89	22791.424
> 4000	39991.93	254	24855.070
Total	24058.84	1265	20069.126

F-Value = 58.8, P < 0.000

The traffic fleet in Jordan (Jordan Traffic Institute, 2011) is distributed into 48.4 % of vehicles that had engine sizes of 1500 cc or less, 27.2 % of vehicles that had engine sizes of 1501-2000 cc, 24.3 % of vehicles that had engine sizes above 2000 cc.

4.11 Effect of Vehicle Registration and Use

Table 13 shows a statistically significant difference in VKT between different vehicle registration categories at 95 % confidence (F-value = 213.8, P < 0.000). The highest VKT value was for transit/cargo vehicles (VKT = 45513 km/year), followed by public vehicles (VKT = 23807 km/year) and then the private vehicles (VKT = 19163 km/year). The transit/cargo vehicles include taxis, service cars, busses, and trucks with green colored license plates. The public vehicles include all governmental vehicles with red colored license plates. The private vehicles include all vehicles with white colored license plates and are not owned by government nor can they be used for paid transit or cargo delivery purposes.

Table 13. Annual Vehicle Kilometers of Travel vs. Vehicle Registration

Vehicle Registration	Mean	N	Std. Deviation
Public	23807.13	40	22081.667
Private	19162.68	997	15479.838
Transit/Cargo	45512.94	228	23237.078
Total	24058.84	1265	20069.126

F-Value = 213.8, P < 0.000

Table 14 shows a statistically significant difference in VKT between different vehicle use categories at 95 % confidence (F-value = 168.5, P < 0.000). The lowest VKT value was for the private passenger vehicles (VKT = 16660 km/year). On the other hand, the highest VKT value was for transit vehicles (VKT = 52184 km/year), followed by cargo vehicles (VKT = 40853 km/year) and then the dual purpose vehicles (VKT = 28109 km/year). The dual purpose vehicle is a pickup with double cabins which may be used for transporting passengers and/or cargo.

Table 14. Annual Vehicle Kilometers of Travel vs. Vehicle Use

Vehicle Use	Mean	N	Std. Deviation
Transit	52183.59	96	17914.141
Cargo	40853.39	192	23240.421
Private Passenger Car	16659.57	722	11842.276
Dual Purpose	28108.69	99	21460.666
Other	17756.31	156	18274.559
Total	24058.84	1265	20069.126

F-Value = 168.5, P < 0.000

4.12 Estimation of VKT for Jordan

As mentioned earlier, this study was mainly conducted to estimate the VKT for the whole country. The surveyed vehicles were chosen carefully and as randomly as possible to cover all vehicle types according to vehicles registration records at the traffic police department. The results for different vehicle types were then expanded according to their corresponding populations to estimate the country VKT. As shown from Table 15, the VKT for the whole country was estimated to be 24,007,867,431 kilometers per year. It should be noted that this procedure does not account for vehicles that do not have Jordanian license plates.

5. Summary and Conclusions

This study aimed at estimating VKT for Jordan and investigating the influencing driver and vehicle characteristics based on a multiple-choice questionnaire that was distributed to a total of 1265 drivers randomly selected from all regions in the country and representing different vehicle types.

Table 15. Estimation of Vehicle Kilometers of Travel for Jordan

Vehicle Type	Mean VKT (km/year)	No. of Registered Vehicles	Total VKT (km/year)
PC	16,709.70	814,486	13,609,816,714
Minibus	52,757.10	17,572	927,047,761
Bus	51,041.60	3,590	183,239,344
SU Truck	36,019.21	134,055	4,828,555,197
Large Truck	53,332.12	20,719	1,104,988,194
Agriculture Vehicle	7,665.00	9,768	74,871,720
Motorcycle	13,359.00	6,008	80,260,872
Special Purpose Vehicle	27,893.30	4,465	124,543,585
Construction Vehicle	10,066.70	11,771	118,495,126
Dual Purpose	28,700.34	102,997	2,956,048,919
Total		1,125,431	24,007,867,431

The study has covered the major driver characteristics (gender, age, education, occupation, family income, family size, and family auto ownership) and vehicle characteristics (type, age, engine size, registration, and use).

The different categories of all driver and vehicle factors had significantly different values of VKT. The VKT value was found to be inversely proportional with driver education level, driver family income, driver family auto ownership, and vehicle age, and directly proportional with vehicle engine size.

The highest VKT values were associated with males, age of 40-49 years old, education of less than high school, occupation of a driver, monthly family income of less than JD 250 (USD 352.5), family size of eight or more, no family auto ownership, trucks and busses, new vehicles (<5 years old), high engine size (>4000 cc), and transit and cargo vehicles.

No significant differences were found between different regions in the country, and the total VKT for Jordan based on different vehicle types and vehicle registration statistics in 2011 was estimated to be around 24 billion kilometers per year.

REFERENCES

[1] AASHTO. (2009) Real Transportation Solutions for Greenhouse Gas Emissions Reductions. Report Number: MCR-1, American Association of State Highway and Transportation Officials, Washington, DC, USA.

[2] Akar, G. and Guldmann, J.M. (2012) Another Look at Vehicle Miles Traveled: Determinants of Vehicle Use in Two-Vehicle Households. Transportation Research Record, Issue 2322, pp. 110–118.

[3] Benekohal, R.F. and Girianna, M. (2002) Evaluation of Methodology for Determining Truck Vehicle Miles Traveled in Illinois. Report Number: ITRC FR 99-2, Illinois Department of Transportation, Springfield, IL, USA.

[4] Byrne, B.F., Croft, J. and Spicer, M. (2008) Retrospective on Process for Estimating Vehicle Miles of Travel on Local Roads in Vermont. Proceedings of the Transportation Research Board 87th Annual Meeting, Washington DC, USA.

[5] Clower, T.L., Ruggiere, P., Bomba, M., Arndt, J.C., Li, J., Edrington, S., and Hendershot, P. (2011) Evaluating the Impact of Transit-Oriented Development**.** Report Number: FHWA/TX-10/0-6511-1, Federal Highway Administration, Washington, DC, USA.

[6] Caltrans. (2008). California Motor Vehicle Stock, Travel and Fuel Forecast. California Department of Transportation, Sacramento, CA, USA.

[7] Davis, B. and Donath, M. (2013) Aggregating VMT Within Predefined Geographic Zones by Cellular Assignment: A Non GPS-Based Approach to Mileage-Based Road Use Charging. Proceedings of the Transportation Research Board 92nd Annual Meeting, Washington DC, USA.

[8] Ferlis, R.A., and Bowman, L.A. (1981) Procedures for Measuring Regional VMT. Transportation Research Record, Issue 815, pp. 1-6.

[9] FHWA. (2012) Highway Statistics Series: Vehicle Miles of Travel (VMT). The Federal Highway Administration website: http://www.fhwa.dot.gov/policy/ohpi/qftravel.cfm Accessed at 10:44 on 21/11/2013.

[10] Frawley, W.E. (2007) Random Count Site Selection Process for Statistically Valid Estimations of Local Street Vehicle Miles Traveled. Transportation Research Record, Issue 1993, pp. 43-50.

[11] Fricker, J.D. and Kumapley, R.K. (2002) Updating Procedures to Estimate and Forecast Vehicle-Miles Traveled . Report Number: FHWA/IN/JTRP-2002/10, Federal Highway Administration, Washington, DC, USA.

[12] Fugitt, B., and Shafizadeh, K. (2010) Measuring Land Use Diversity and Correlating Its Relationship with VMT. Proceedings of the Transportation Research Board 89th Annual Meeting, Washington DC, USA.

[13] Hoang, L.T. and Poteat, V.P. (1980) Estimating Vehicle Miles of Travel by Using Random Sampling Techniques. Transportation Research Record, Issue 779, pp. 6-10.

[14] Jordan Traffic Institute (2011) Traffic Accidents in Jordan-2011. Public Security Department, Amman, Jordan.
[15] Lave, C.A. (1994) State and National VMT Estimates: It AIN'T Necessarily So. University of California Transportation Center, Berkeley, CA, USA.
[16] McMullen, B.S. and Eckstein, N. (2012) Relationship Between Vehicle Miles Traveled and Economic Activity. Transportation Research Record, Issue 2297, pp. 21-28.
[17] Morey, J.E., Niemeier, D.A., and Limanond, T. (2004) Statistical Framework Using GIS to Estimate Unpaved Road VMT for PM-SUB-10 Emission Inventories. Journal of Urban Planning and Development, Volume 130, Issue 2, pp. 83-93.
[18] NCSA (2013) Early Estimate of Motor Vehicle Traffic Fatalities in 2012. Report Number: DOTHS811741, Traffic Safety Facts - Crash Stats, National Center for Statistics and Analysis, Washington, DC, USA.
[19] Pickrell, D., Pace, D., West, R. and Hagemann, G. (2012) Developing a Multi-Level Vehicle Miles of Travel Forecasting Model. Proceedings of the Transportation Research Board 91st Annual Meeting, Washington, DC, USA.
[20] Rentziou, A., Gkritza, K. and Souleyrette, R. (2012). VMT, energy consumption, and GHG emissions forecasting for passenger transportation. Transportation Research Part A: Policy and Practice, Volume 46, Issue 3, pp. 487-500.
[21] Rooney, M.S. and Srinivasan, S. (2008) Making Best Estimates of Spatial Distribution of Average Household Vehicle Miles Traveled: Assays in San Francisco Bay Area and Boston Metropolitan Region. Proceedings of the Transportation Research Board 87th Annual Meeting, Washington DC, USA.
[22] Salon, D., Boarnet, M.G., Handy, S., Spears, S., and Tal, G. (2012) How do local actions affect VMT? A critical review of the empirical evidence. Transportation Research Part D: Transport and Environment, Volume 17, Issue 7, 2012, pp. 495-508.
[23] Smith, B.L., Qi, Y., and Park, H. (2006) A Methodology to Estimate Vehicle Miles Traveled (VMT) Fractions as an Input to the Mobile Emission Model. Report Number: FHWA/VTRC 06-CR11, Federal Highway Administration, Washington, DC, USA.
[24] Teng, H. and Wang, N. (2011) Estimating vehicle miles traveled combined with ITS data. Transportation Planning and Technology, Volume 34, Issue 8, pp. 777-794
[25] Toth, G. (2007). Reducing Growth in Vehicle Miles Traveled: Can We Really Pull It Off?. Monograph Title: Driving Climate Change: Cutting Carbon from Transportation. Academic Press, Burlington, MA, USA, pp. 129-142.
[26] Wang, T. and Chen, C. (2012) Understanding the Changes of Vehicle Miles Travelled in Response to Fuel Price and Fuel Efficiency for Different Income Groups. Proceedings of the Transportation Research Board 91st Annual Meeting, Washington, DC, USA.
[27] Wang, Y.D. (2007) Estimating Vehicle-Miles-Traveled by Vehicle Class for the State of Delaware. Delaware Department of Transportation, Dover, DE, USA.
[28] Zhang, L. and He, X. (2013) Feasibility and Advantages of Estimating Local Road VMT Based on GPS Travel Data. Proceedings of the Transportation Research Board 92nd Annual Meeting, Washington DC, USA.