Study on Estimation of VKT and Fuel Consumption in Khon Kaen City, Thailand

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Abstract: Vehicle Kilometer of Traveled is one of most meaningful indicators to represent road transport in particular area. It is an essential data in order to observe vehicle usage and estimate amount of CO2 emissions from road transport. Especially, in developing cities, estimation of CO2 emission based on VKT is the applicable approach. However, it is not sufficiently available in Thailand. Therefore, in this study, VKT by vehicle types were measured by applying method based on records of odometer and conducting driver's interview survey in Khon Kaen City, Thailand, as case study. Results revealed that accumulated VKT has high positive relation with vehicle age but annual VKT have high negative relation with vehicle age. Moreover, the study surveyed fuel consumption per distance to develop fuel consumption rate by vehicle type. Results revealed that fuel efficienciess of Sedan and Van & Pickup Truck are higher than twice of Motorcycle.

Keywords: Vehicle Kilometers of Traveled (VKT), Odometer, Fuel Efficiency, Vehicle Age, Khon Kaen City

1. INTRODUCTION

CO2 emission from road transport could be estimated by multiplying the emission factors by speed, vehicle type and fuel type to traffic conditions by each road section. However, the emission factors which used to be developed by measuring emission from local vehicles on a chassis dynamometer or using mobile measurement equipments, are not available in developing cities so that more simplified approach might be used. Estimation of CO2 emission based on fuel consumption by vehicle activity is one of such approach. Since fuel consumption by vehicle types could be obtained easily, fuel consumption could be also acquired if Vehicle Kilometer of Traveled (VKT) which is represented local vehicle activity could be measured. According to previous studies, the measurement method of VKT based on odometer readings is applicable method in developing cities.

Thus, the objectives of this study are to examine feasibility of the measurement method of VKT and fuel efficiency based on odometer readings by analyzing VKT and fuel efficiency measured in the Khon Kean city, Thailand, a representative of developing cities.

The content of this paper is separated into follow sessions. The second part explores the previous relating studies. The third part displays the research methodology. The fourth part presents the results and discussions. The fifth part presents the application of developed models. And, the final part gives the conclusions and recommendations of this research.

2. LITERATURE REVIEW

2.1 Odometer Readings

Kumapley and Fricker (1999) pointed out that the odometer readings method has a number of other shortcomings that render it impractical and unreliable. Possible sources of error included as follows.

1) Odometer calibration errors due to worn-out odometer cables.
2) Reporting errors.
3) Second-party readings or transcription errors.
4) Odometer rollovers.
5) Odometer tampering.
6) Vehicle drop-out caused by accidents or aged vehicles.
7) Out-of-area traveled likely to be considered in-area travel.

2.2 VKT Estimation Based on Odometer Readings in Thailand

Udomsri and Punravee (2003) developed vehicle distance traveled model to calculate annual VKT which mainly included daily distance at Chiang Mai urban area in 2003. The VKT models were developed based on odometer readings and travel characteristics of household travelers. The results indicated that average daily distance traveled by household traveler and frequency of using vehicle in a week significantly affect to annual VKT of household vehicles.

Limanond et al., (2009) estimated VKT at Bangkok and Nakhon Ratchasrima based on records of odometer under the ATRANS (Asian Trasportation Research Society) research project in 2009. This study surveyed 9 types of vehicle by classification of the Department of Land Transport. As the result, it found economical factors such as GDP, income level, etc. and land use characteristics such as population density, etc. However, VKT survey based on employing appropriate method has never been conducted in other cities in Thailand.

2.3 Fuel Consumption and Emissions Measurement and Estimation by Technology

Rather than traditional methods to measure and estimate fuel consumption and emissions of traveling traffic, there are currently many advanced technology approaches were proposed as follows.

Chang et al. (2013) estimated CO2 emissions of real-time traffic by using intelligent transportation system technologies.

Satiennam et al. (2012) developed the onboard measurement system to measure simultaneously speed profile, emissions and fuel consumption of motorcycle driving on the real road. The collected on-road data was applied to develop on-road emission factors, emission rate models, and fuel consumption rate model for estimating emissions and fuel consumption with transportation and traffic models

2.4 Fuel Consumption Survey in Japan

Ministry of Land, Infrastructure, Transportation and Tourism in Japan has been surveying about fuel consumption etc. from vehicles since 2010. This survey is employed a *Mantan* method that can be easily and accurately for estimating fuel consumption. The agency has been carrying out for 5,000 vehicles per a month.

However, this survey hasn't been conducted on large scale in Thailand. Figure 1 shows how to survey Mantan method. Firstly, the investigator record the odometer on January 1st, during driver's filling up the tank at the gas station. The next day, the investigator read the odometer again. As the result, we can find this vehicle's fuel consumption is 10 liter during survey period (2 days), and then this vehicle's travel distance is 100km. Thus, the vehicle's fuel efficiency is calculated 10 km per a liter.

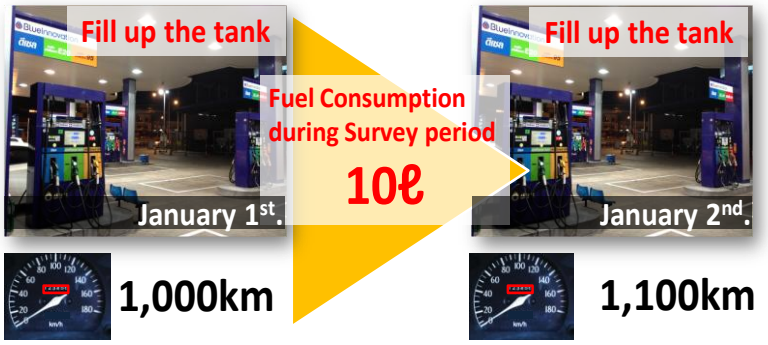

Figure 1. Mantan method

3. RESEARCH METHODOLOGY

The flow chart of research methodology of this study is displayed in Figure 2. Each step of research methodology is described in detail as follows.

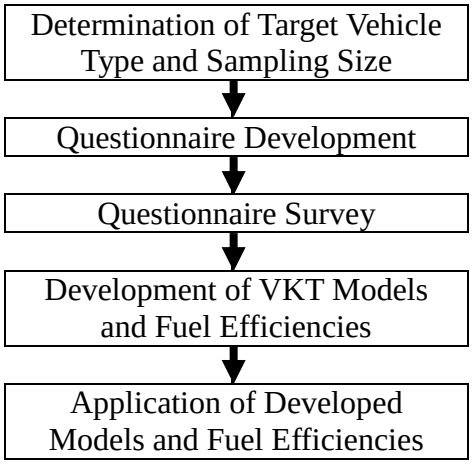

Figure 2. Flow chart of research methodology

3.1 Case Study

This study selected the Khon Kaen City as a case study. Khon Kaen City is located in Khon Kaen province, a core of the governmental province of the Northeast part of Thailand. The City has an area of 46 km^2. There are 111,294 populations with 2,419 people/km^2 density (Khon Kaen Municipality, 2013).

3.2 Determination of Target Vehicle Type and Sampling Size

Regarding to determination of the target vehicle type, this study considered the type of vehicle classified by the Department of Land Transport of Thailand (DLT, 2013) and selected three major vehicle types, including 1) Sedan (not more than 7 passengers), 2) Van & Pickup Truck and 3) Motorcycle were selected as a target vehicle type because their percentages of usage are high.

According to determination of sampling size, this study applied the Equation (1) (Yamane, 1967) to determine a number of samplers (n). A number of populations (N) are a number of registered vehicles in the study area (Khon Kaen Land Transport Office, 2013). The minimum number of required samplers by each vehicle type is displayed in Table 1.

$$n = N / (1 + N e^2) \quad (1)$$

Where

N = Number of Population (Registered Vehicles)
e = Error of Random Sample Size (0.05)

Table 1. Minimum number of required samplers

No.	Type of Vehicle	Vehicle Register* (N)	Minimum Number of Required Samplers (n)
1	Sedan	88,402	398
2	Van & Pickup Truck	97,826	398
3	Motorcycle	190,153	399

* Number of registered vehicles in year 2012

3.3 Questionnaire Development

The questionnaire was designed to interview the sampler in all study issues concerning to VKT and fuel consumption. The questionnaire is separated into 2 main parts. The first part consists of the questions relating to vehicle information, including vehicle age, records of odometer, fuel type, fuel full, vehicle condition (e.g. new or used car), and purpose of vehicle usage (e.g. personal or commercial car). The second part consists of the questions relating to driver information, including gender, age, personal income, household income, occupation, and residential location.

3.4 Questionnaire Survey

This study conducted the interview survey with sampling drivers who visited three main gas stations in Khon Kaen City, as displayed in Figure 3. Two gas stations are located along national highway No.2, and the another gas station is located inside of Khon Kaen University.

To obtain the fuel consumption, the interviewer had to find out the sampling driver who filled fully the fuel at first time and backed to refill fully the fuel for the second time at the same gas station.

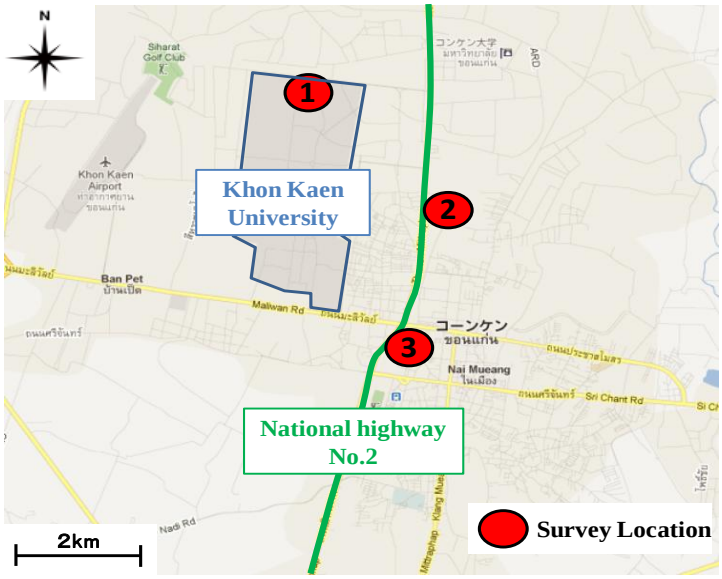

Figure 3. Locations of questionnaire survey

3.5 Development of VKT Models and Fuel Efficiencies

This study applied the regression analysis to develop the VKT models by vehicle type. The VKT model would represent the relation between average accumulated VKT (km) and vehicle age (year). The vehicle age, when obtained samplers more than 10 samplers, would be included for developing model because the vehicle age with number of samples less than 10 samplers may result in low relation between average accumulated VKT and that vehicle age (Limanond et al., 2009).

The fuel efficiencies by vehicle type were calculated by an amount of fuel consumed by a vehicle which traveled along the particular distance.

4. RESULTS AND DISCUSSIONS

4.1 Developed VKT Model for Sedan

As a result of questionnaire survey, this study obtained 1,572 samplers, excluding samplers in vehicle age group obtained less than 10 samplers, could be used in the regression analysis to develop the VKT model for Sedan. The average accumulated VKT and obtained number of samples by vehicle age are shown in Table 2. As result of regression analysis displayed in Figure 4, the positive Logarithm curve yields the highest relation between vehicle age (year) and accumulated VKT (km) with correlation coefficients (R^2) = 0.94. It means that the vehicle age increases, the accumulated VKT also increases but the increasing rate decreases continuously year by year. Beside, the negative Logarithm curve yields the highest relation between vehicle age (year) and annual VKT (km) with R^2 = 0.86, It means that vehicle age increases but the annual VKT decreases. It describes that the drivers, who have the newer car, tend to drive the newer cars more often and longer distance, but the older cars tend to be broken and spent more time in the repair shop.

Table 2. Average accumulated VKT of Sedan

Vehicle Age (year)	Average Accumulated VKT (km)	Obtained Samplers	Vehicle Age (year)	Average Accumulated VKT (km)	Obtained Samplers
1	29,833	451	12	285,512	15
2	55,763	350	13	219,965	10
3	81,408	217	14	191,532	4
4	106,891	129	15	300,564	9
5	119,838	101	16	283,474	6
6	122,271	89	17	241,802	4
7	132,085	78	18	173,097	1
8	156,218	75	19	280,459	1
9	161,797	30	20	245,904	6
10	196,184	52	24	208445	2
11	178,768	7			

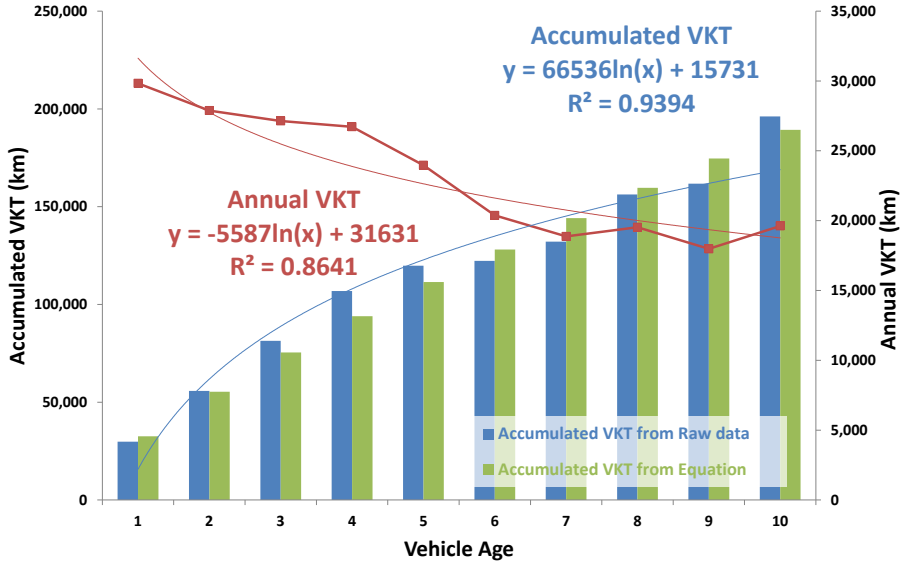

Figure 4. Accumulated VKT and annual VKT of Sedan

In addition, the accumulated VKT models of Sedan were developed by fuel type as presented in Figure 5. The annual VKT of Sedan by fuel type is presented in Table 3. Results reveal that CNG vehicle (Bi-fuel) has the highest accumulated VKT and annual VKT by each vehicle age because CNG price is cheapest among other fuel types as shown in Table 4. It implies that VKT of Sedan decreases with more expensive fuel price as similar to the finding of previous study (Udomsri and Punravee, 2003) which also stated that increasing fuel price had an effect on the reduction of fuel consumption of household vehicles.

Moreover, this study developed the accumulated VKT models by driver's personal income as presented in Figure 6. The annual VKT of Sedan by personal income is shown in Table 5. Results reveal that the drivers with higher income have a higher accumulated and annual VKT. It implies that VKT increases with higher personal income of driver.

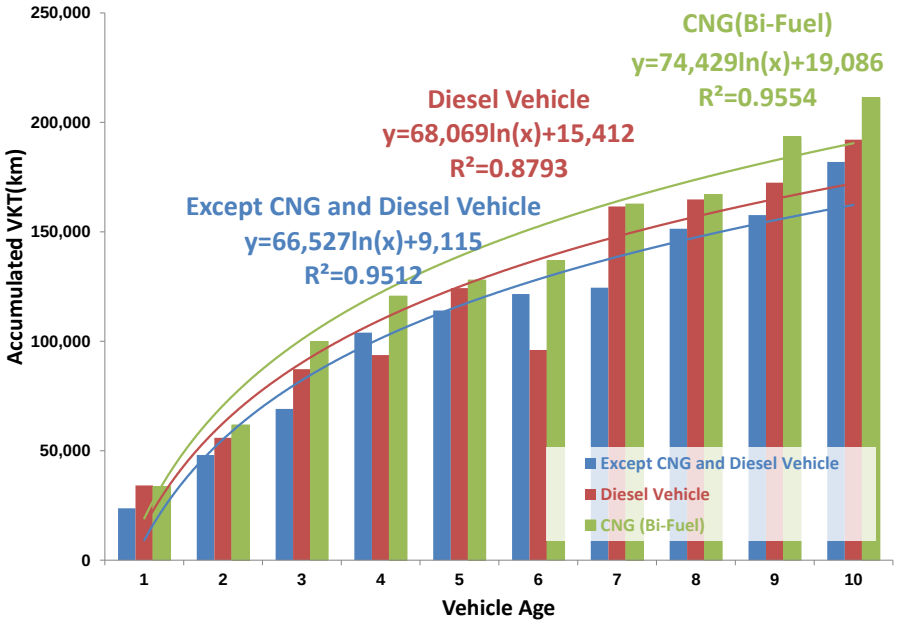

Figure 5. Accumulated VKT of Sedan by fuel type

Table 3. Annual VKT of Sedan by fuel type

Type of Fuel	Annual VKT (km)
Except CNG and Diesel Vehicle	21,230
Diesel Vehicle	23,754
CNG (Bi-Fuel)	26,304

Table 4. Fuel price during 2012

	Gasoline (Baht)	Gasohol-E10 (Baht)	Gasohol-E20 (Baht)	Gasohol-E85 (Baht)	Diesel (Baht)	CNG (Baht)
Octane 95	47	38	34	22	30	10
Octane 91	43	36				

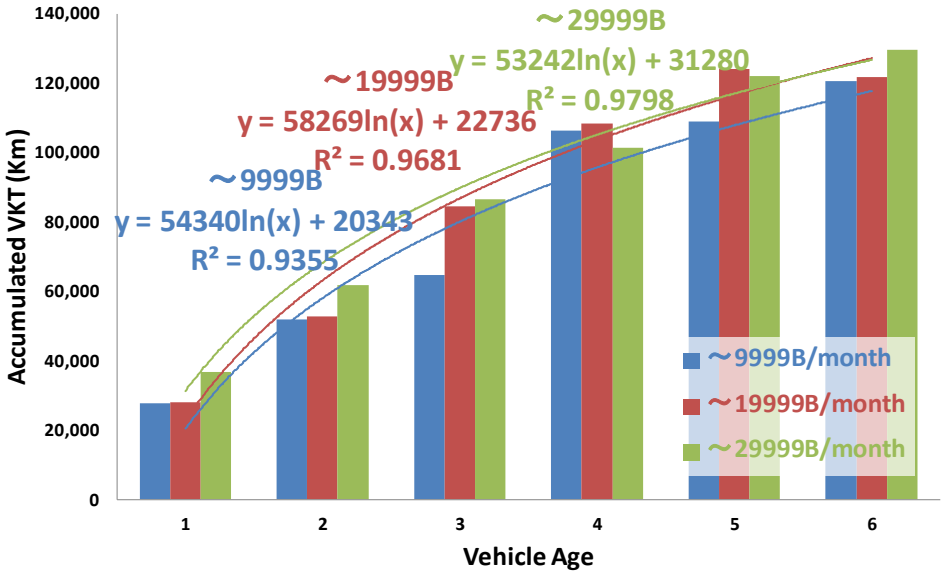

Figure 6. Accumulated VKT of Sedan by personal income

Table 5. Annual VKT of Sedan by personal income

Personal Income (Baht)	Annual VKT (km)
~9,999B	23,908
~19,999B	25,807
~29,999B	27,976

4.2 Developed VKT Model for Van & Pickup Truck

As a result of questionnaire survey, this study obtained 493 samplers that could be included in the regression analysis to develop the VKT model for Van & Pickup Truck. The average accumulated VKT and number of obtained samplers by vehicle age are shown in Table 6. As result of regression analysis displayed in Figure 7, the positive Logarithm curve yields the highest relation between vehicle age (year) and accumulated VKT (km) with correlation coefficients (R^2) = 0.67. It means that the vehicle age increases, the accumulated VKT also increases but the increasing rate decreases continuously year by year. Beside, the negative Logarithm curve yields the highest relation between vehicle age (year) and annual VKT (km) with R^2 = 0.74, It means that vehicle age increases but the annual VKT decreases. The reason is similar to those of Sedan as the drivers, who have the newer car, tend to drive the newer cars more often and longer distance, but the older cars tend to spend longer time in the garage.

In addition, the accumulated VKT models of Van & Pickup Truck were developed by fuel type as presented in Figure 8. The annual VKT of Van & Pickup Truck by fuel type is presented in Table 7. Results reveal that CNG vehicle (Bi-fuel) has the highest accumulated VKT and annual VKT by vehicle age because CNG price is cheapest among other fuel types as shown in Table 4. It implies that VKT of Van & Pickup Truck decreases with condition of more expensive fuel price as similar as those of Sedan.

Furthermore, this study developed the accumulated VKT models by driver's personal income as presented in Figure 9. The annual VKT of Van & Pickup Truck by personal income is shown in Table 8. Results reveal that the drivers with low (<10,000 Baht) and middle income (10,000-19,999 Baht) have rather same accumulated VKT but drivers with high income (20,000-29,999 Baht) have a higher annual VKT. It may imply that Vans & Pickup Trucks, driven by drivers with low and middle income (officers), are the commercial or office vehicles. The VKT of commercial or office vehicle depends on the logistic and business trip of that office. But the Vans & Pickup Trucks, driven by drivers with high income, might be personal vehicles.

Table 6. Average accumulated VKT of Van & Pickup Truck

Vehicle Age (year)	Average Accumulated VKT (km)	Obtained Samplers	Vehicle Age (year)	Average Accumulated VKT (km)	Obtained Samplers
1	64,604	161	14	306,034	1
2	75,864	72	15	357,252	9
3	74,532	59	16	225,920	4
4	99,493	59	17	365,315	4
5	99,481	32	18	368,697	2
6	113,149	28	19	280,459	5
7	139,170	31	20	335,952	1
8	175,049	18	23	682,291	1
9	181,897	13	26	486,851	1
10	256,357	20	30	339,465	6
11	272,643	5	32	750,351	1
12	209,180	9	34	590,008	1
13	346,710	3	35	999,782	1

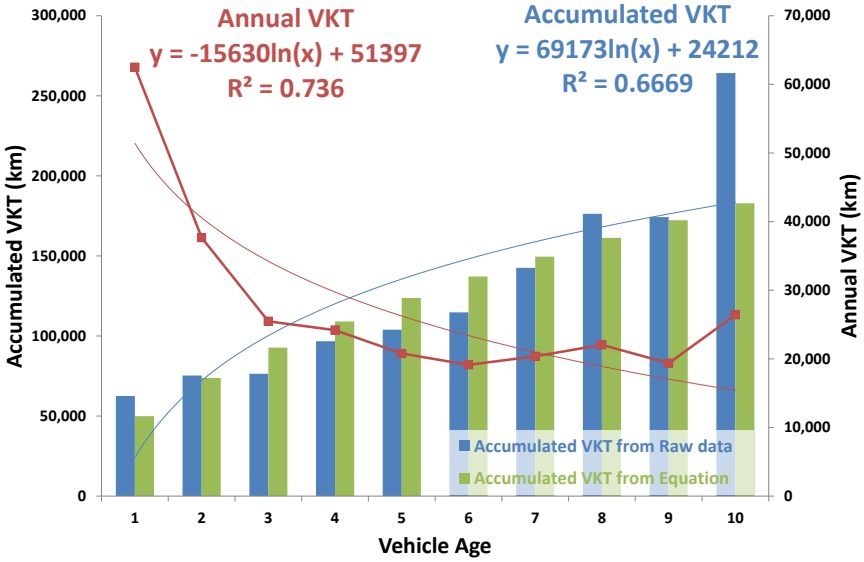

Figure 7. Accumulated VKT and annual VKT of Van & Pickup Truck

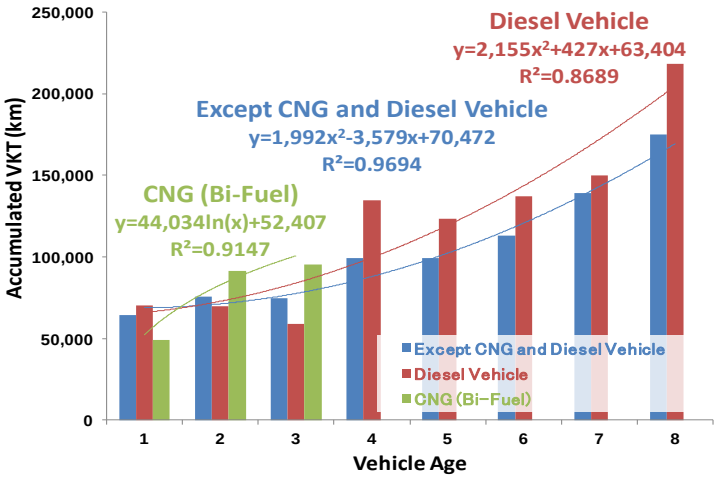

Figure 8. Accumulated VKT of Van & Pickup Truck by fuel type

Table 7. Annual VKT of Van & Pickup Truck by fuel type

Type of Fuels	Annual VKT (km)
Except CNG and Diesel Vehicle	29,096
Diesel Vehicle	31,807
CNG (Bi-Fuel)	42,263

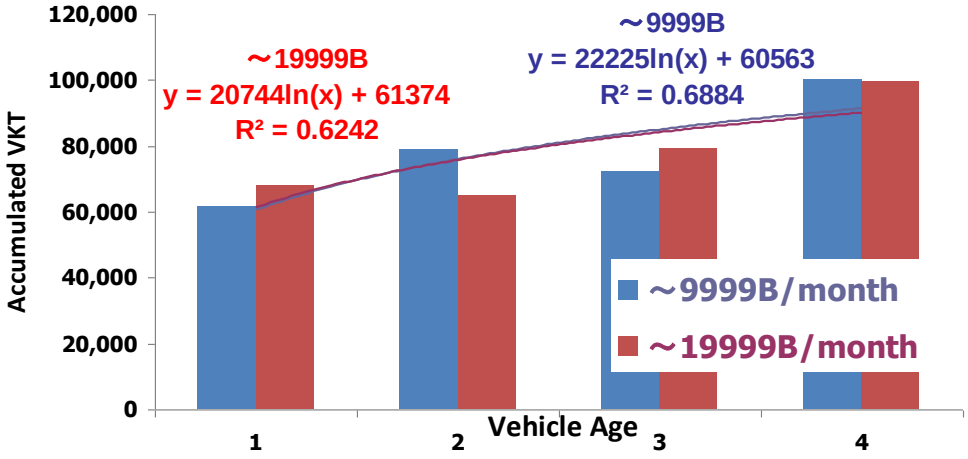

Figure 9. Accumulated VKT of Van & Pickup Truck by personal income

Table 8. Annual VKT of Van & Pickup Truck by personal income

Personal Income (Baht)	Average Annual VKT (km)
~9,999B	37,572
~19,999B	37,895
~29,999B	43,347

4.3 Developed VKT Model for Motorcycle

As a result of questionnaire survey, this study obtained 895 samplers that could be used to develop the VKT model for Motorcycle by a regression analysis. The average accumulated VKT and number of obtained samplers by vehicle age are shown in Table 9. As result of regression analysis displayed in Figure 10, the positive Logarithm curve yields the highest relation between vehicle age (year) and accumulated VKT (km) with $R^2 = 0.91$. Similarly to Sedan and Van & Pickup Truck, it reveals that the vehicle age increases, the accumulated VKT also increases but the increasing rate decreases continuously year by year. The reason might be same as those of Sedan and Van & Pickup Truck. However, relation of annual VKT (km) and vehicle age (year) is presented by Parabola curve.

In addition, the accumulated VKT models of Motorcycle were developed by fuel type as presented in Figure 11. The annual VKT of Motorcycle by fuel type is presented in Table 10. Results state that accumulated and annual VKT of motorcycle using Gasohol 91 and Gasohol 91-E10 are rather similar.

Furthermore, this study developed the accumulated VKT models by motorcyclist's personal income as presented in Figure 12. The annual VKT of Motorcycle by personal income is shown in Table 11. Results reveal that the motorcyclists with higher income have a higher accumulated and annual VKT. It implies that VKT increases with higher personal income of motorcyclists as similar to those of Sedan. However, the accumulated VKT of

Motorcycle is very high relation with income of motorcyclist since motorcycle usually used by low income people, VKT is thus significantly influenced by income of motorcycle rider.

Table 9. Average accumulated VKT of motorcycle

Vehicle Age (year)	Average Accumulated VKT (km)	Obtained Samplers	Vehicle Age (year)	Average Accumulated VKT (km)	Obtained Samplers
1	6,385	159	11	67,390	3
2	12,894	174	12	52,026	12
3	22,290	138	13	46,808	2
4	29,646	123	14	5,443	1
5	36,186	116	15	34,616	9
6	38,979	59	16	12,573	1
7	40,056	57	17	214,111	1
8	52,285	30	18	27,414	2
9	39,667	15	19	49,516	1
10	43,944	24			

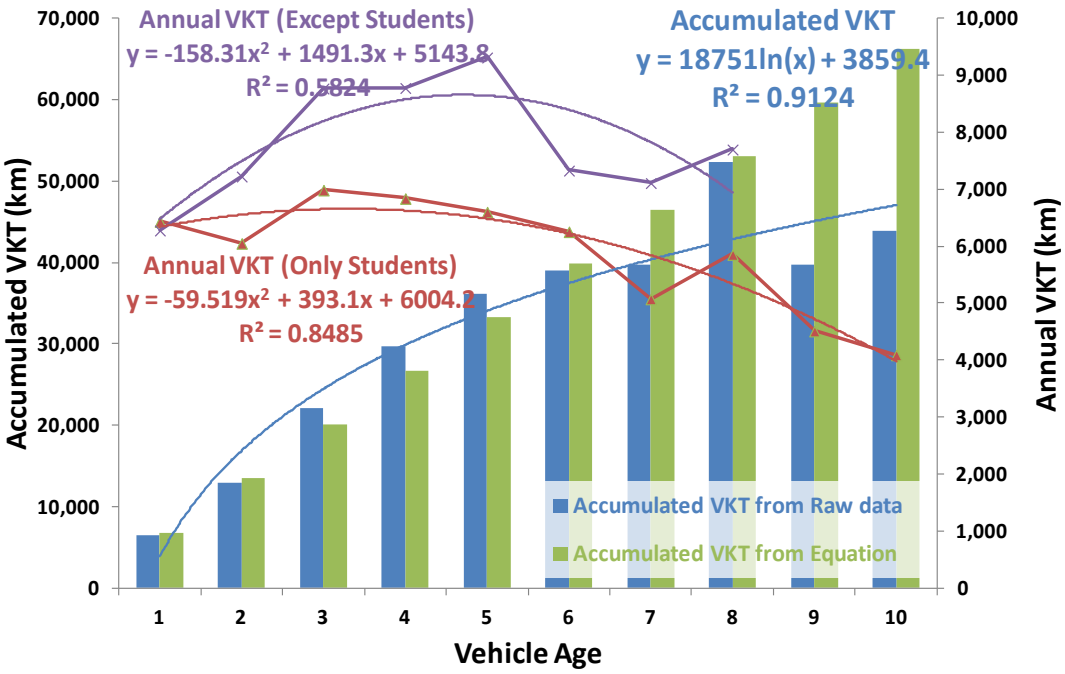

Figure 10. Accumulated VKT and annual VKT of motorcycle

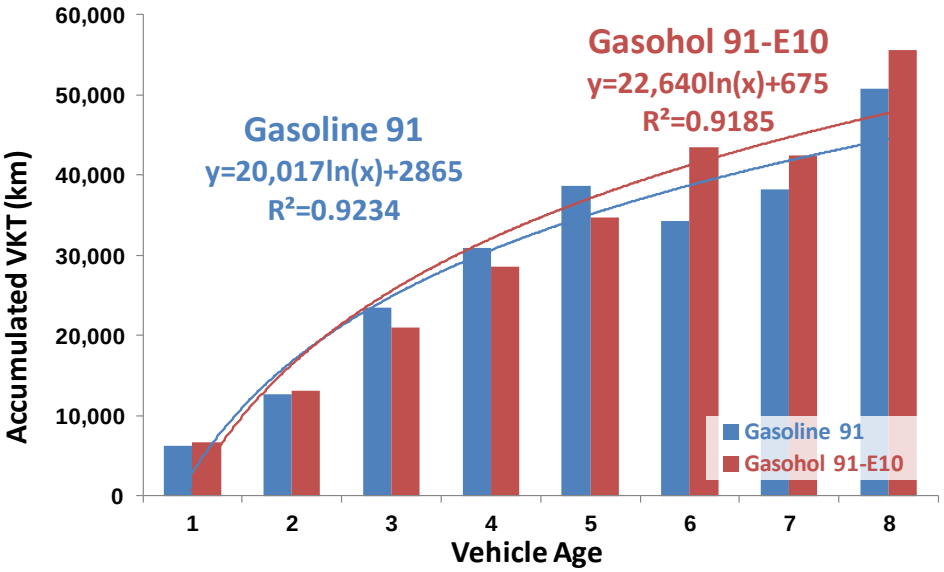

Figure 11. Accumulated VKT of motorcycle by fuel type

Table 10. Annual VKT of motorcycle by fuel type

Type of Fuels	Annual VKT (km)
Gasoline 91	6,664
Gasohol 91-E10	6,808

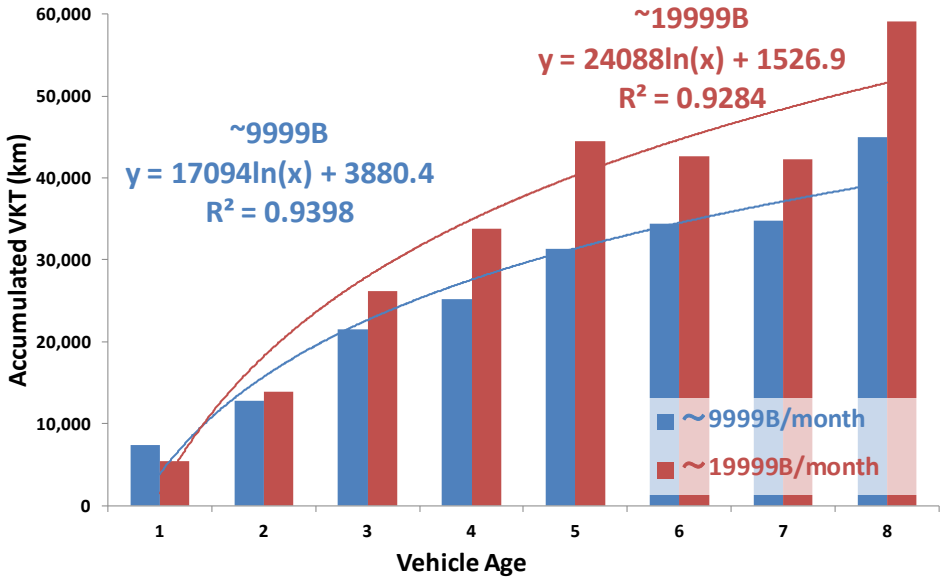

Figure 12. Accumulated VKT of motorcycle by personal income

Table 11. Annual VKT of motorcycle by personal income

Personal Income (Baht)	Annual VKT (km)
~9,999B	6,227
~19,999B	7,367

4.4 Comparison of VKT of Cities in Thailand

This part presents a comparison of accumulated and annual VKT of three major cities in Thailand, including Khon Kaen City, Nakhon Ratchasima City, and Bangkok. The VKT data of Nakhon Ratchasima City and Bangkok was given by the previous study (Limanond et al., 2009). The comparative curves of accumulated VKT by Sedan, Van & Pickup Truck and Motorcycle are presented in Figure 13, 14, and 15, respectively. The annual VKT of cities is shown in Table 12. As the comparison results, the accumulated and annual VKT of Sedan and Van & Pickup Truck of Bangkok are the most highest among other cities. Those VKT of Sedan and Van & Pickup Truck of Nakhon Ratchsima City are higher than those VKT of Khon Kaen City. But, the accumulated and annual VKT of Motorcycle of Khon Kaen City are the most highest among other cities. It implies that the accumulated and annual VKT of Sedan and Van & Pickup Truck are higher as the city scale (e.g. area, economic, population, and etc.) is larger. Vice versa, the accumulated and annual VKT of Motorcycle are higher as the city scale is smaller because the people can travel through smaller city by motorcycle but people living in larger city need to travel by passenger car.

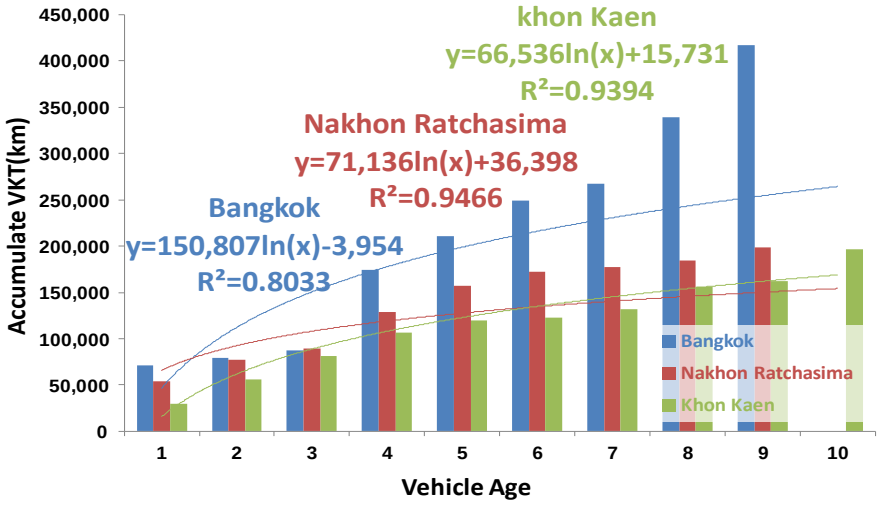

Figure 13. Accumulated VKT of Sedan by city

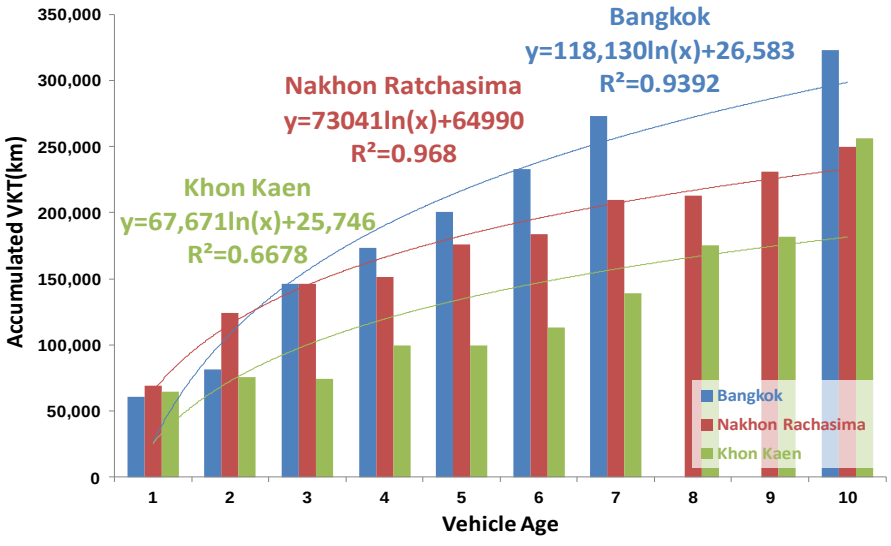

Figure 14. Accumulated VKT of Van & Pickup by city

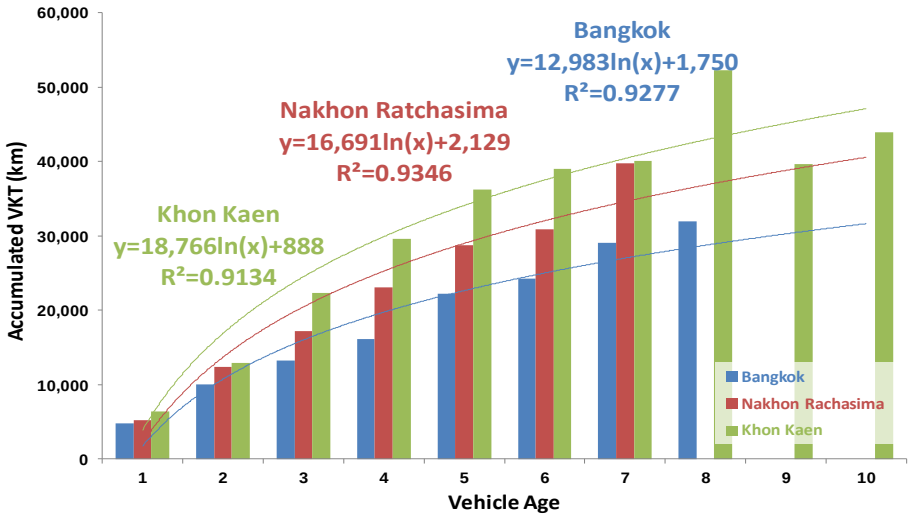

Figure 15. Accumulated VKT of Motorcycle by city

Table 12. Annual VKT by city

City	Annual VKT (km)		
	Sedan	Van & Pickup Truck	Motorcycle
Bangkok	31,368	32,475	4,015
Nakhon Ratchasima	15,640	18,140	5,662
Khon Kaen	23,191	27,862	6,247

4.5 Developed Fuel Efficiencies

This study collected 466 sedans for fuel consumption survey. The fuel type of Sedan was classified into Gasoline, Gasohol, and Diesel. The sampling frequency is distributed from 8 – 14 km/l as displayed in Table 13.

Table 13. Number of Sedan samplers by fuel efficiency and fuel type

Fuel Efficiency (km/l)	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	Total
Gasoline, Gasohol (Number)	0	0	1	53	62	54	58	50	61	61	1	0	401
Diesel (Number)	0	1	0	5	4	9	9	16	10	11	0	0	65

This study collected 389 motorcycles for fuel consumption survey. The fuel type of Motorcycle was classified into Gasoline and Gasohol. The sampling frequency is distributed from 20 – 32 km/l as displayed in Table 14.

Table 14. Number of Motorcycle samplers by fuel efficiency and fuel type

Fuel Efficiency (km/l)	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	
Gasoline (Number)	0	2	2	2	2	2	3	41	34	35	9	9	
Gasohol (Number)	0	0	3	1	3	3	4	35	31	33	11	18	
Fuel Efficiency (km/l)	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	
Gasoline (Number)	5	10	2	7	5	0	6	3	1	1	0	0	
Gasohol (Number)	23	4	7	8	7	5	2	0	1	3	2	0	
Fuel Efficiency (km/l)	**39**	**40**	**41**	**42**	**43**								Total
Gasoline (Number)	0	2	0	0	0								183
Gasohol (Number)	0	1	0	0	1								206

Averages of fuel efficiency resulted by this study were compared with those calculated from the LEAP (the Long Energy Alternatives Planning System) model in Thailand's provincial regions as shown in Table 15. LEAP is a widely-used software tool for energy policy analysis and climate change mitigation assessment (Heaps, 2012). As comparison result, the values of fuel efficiency obtained by this study are close to those from LEAP.

Table 15. Comparison of fuel efficiency between this study and LEAP

	Gasoline (km/l)	Gasohol (km/l)	Diesel (km/l)	LPG (km/kg)	CNG (km/kg)
Sedan	11.05		11.49	-	-
	<12.28>*	<12.43>*	<11.96>*	<9.87>*	<10.85>*
Motorcycle	24.67	25.41		—	
	<25.75>*	<25.92>*			

* <LEAP Values>

5. APPLICATION TO ESTIMATE FUEL EFFICIENCY AND CO2 EMISSION

This study finally applied the developed VKT models and fuel efficiencies to estimate fuel consumption and CO2 emission from sedan and motorcycle in Khon Kaen City. Figure 16 shows calculation formula for estimating fuel consumption and CO2 emission.

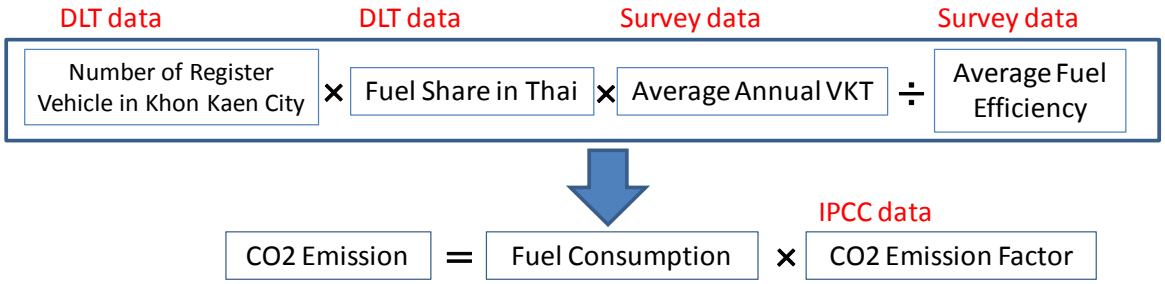

Figure 16. Calculation formula

To estimate fuel consumption, the calculation formula in Figure 16 was applied. The variables in the formula were given as follows. The number of registered vehicle in Khon Kaen City was given in Table 1 (Khon Kaen Land Transport Office, 2013). The percentage of fuel sharing, collected in provincial regions, was given by the Department of Land Transport,

Thailand, as presented in Table 16. Average annual VKT, displayed in Table 17, and average fuel efficiency, shown in Table 18, were measured and developed by this study. It notices that fuel efficiencies of LPG and CNG were given by LEAP since this study did not collect the data about fuel efficiency of LPG and CNG. The results of fuel consumption (kl/year) calculation are presented in Table 19. Thus, the total fuel consumption by vehicles in Khon Kaen city is approximately 223,556 kl/year.

To estimate amount of CO2 emission, the resulted fuel consumption was multiplied by CO2 emission factor (t-CO2/kl), as displayed in Table 20. The results of CO2 emission estimation (t-CO2/year) are presented in Table 21. Finally, the total CO2 emission from vehicles in Khon Kaen City is about 525,072 t-CO2/year.

Table 16. Fuel share of vehicle type

Type of Fuel	Fuel Share (%)	
	Sedan	Motorcycle
Gasoline	34.30	74.56
Gasohol	34.50	25.44
Diesel	30.31	-
LPG	0.43	-
CNG	0.43	-

Table 17. Collected Annual VKT

Type of Fuel	VKT (km/year)	
	Sedan	Motorcycle
Gasoline	21,230	6,664
Gasohol		6,808
Diesel	23,754	-
LPG	26,304	-
CNG		-

Table 18. Average fuel efficiency

Type of Fuel	Fuel Efficiency (km/l)	
	Sedan	Motorcycle
Gasoline	11.05	26.47
Gasohol		25.41
Diesel	11.49	-
LPG	<9.87>*	-
CNG	<10.85>*	-

* <LEAP Values>

Table 19. Estimated fuel consumption by vehicle

Type of Fuel	Unit	Estimated Fuel Consumption (Unit/year)	
		Sedan	Motorcycle
Gaoline	kl	58,253	38,298
Gasohol	kl	58,650	12,961
Diesel	kl	55,394	—
LPG	t	949	
CNG	t	949	
Total		223,556 kl/year*	

* excluding LPG and CNG consumption

Table 20. CO2 Emission Factor

Type of Fuel	Unit	CO2 Emission Factor (t-CO2/Unit)
Gasoline	kl	2.1896
Gasohol	kl	2.1896
Diesel	kl	2.7446
LPG	t	2.8400
CNG	t	2.2472

Table 21. Estimation CO2 Emission

Type of Vehicle	CO2 Emission (t-CO2/year)
Sedan	412,835
Motorcycle	112,236
Total	525,072

6. CONCLUSIONS AND RECOMMENDATIONS

This study presented the applicable approaches to measure and develop the VKT models and fuel efficiency for the developing cities. The VKT and fuel consumption by vehicle type were measured by recording the odometer and conducting driver's interview survey. The Khon Kaen City of Thailand was selected as case study. The accumulated and annual VKT models as well as fuel efficiencies of three vehicle types, including Sedan, Van & Pickup Truck and Motorcycle in Khon Kaen City were developed. The results of VKT model development revealed that accumulated VKT has high positive relation with vehicle age but annual VKT have high negative relation with vehicle age. The vehicle type, fuel type and driver's income significantly influenced to the accumulated and annual VKT of vehicle. The results of fuel efficiency development revealed that fuel consumption rates of Sedan and Van & Pickup Truck are higher than twice of Motorcycle. Finally, the Mantan method was approved to be applied for collecting the fuel efficiency data in the city of Thailand.

As the recommendations, the future study should be considered on the issues of application of advanced technologies to measure and estimate more effectively, efficiently and economically VKT, fuel consumption as well as emissions of all types of vehicle.

ACKNOWLEDGEMENTS

This study is granted by the Japan Ministry of Environment “Global Environment Research Fund (S-6)” The authors would like to express gratitude for a cooperation of Dr. Paramet and Miss. Oraphan at the Prince of Songkla University as well as Mr. Kittiphope and Mr. Supakorn at the Khon Kaen University.

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