An Energy End-Use Demand Model for Predicting the Fuel Usage in the Transport Sector of Thailand

by

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Abstract

In this article, a mathematical model is developed and implemented in software for predicting fuel demand in Thailand's transport sector at the end-use level. The model has been tested by using data from 2006-2012. The interface software was specifically developed for ease of use. In addition, the software was designed to allow the users to change the variables according to different conditions. The number of vehicles predicted by the model in 2010 matches the actual data with a slight difference of 0.4%. The fuel projection was 13% lower than reported data in 2010. The results from our model is also compared with a previous model [1] for the years 2010, 2015, and 2020. The projections in both number of vehicle and fuel consumption differ only 6%, 3% and 0.05% respectively from the previous work results. Furthermore, for the same period, the fuel consumption estimates differ 13%, 7% and 2% respectively from the previous work results.

Keywords: End-Use Model, Energy Demand, Transport Sector

1. Introduction

Thailand has a large number of vehicles on the roads and it is increasing every year. The increasing number of cars directly causes the increased demand for fuel energy. Based on Thailand's final energy consumption data, it is found that the transportation sector has the highest proportion of energy consumption compared to other sectors. Moreover, 90 percent of the transportation sector still relies on the use of refined oil which is imported from abroad. Over the years, the government and the Ministry of Energy have promoted a policy to push for energy consumption reduction in the transportation sector and also adopted a policy to develop alternative energy sources such as ethanol, biodiesel, and natural gas to fully meet the energy needs in the transportation sector. However, the productions of biodiesels are limited, and it is not sufficient. Therefore, crude oil is still the main fuel that Thailand needs to import continuously in the years ahead, as well as the natural gas to meet the demand and usage in the country. It is a worldwide effort to understand and analyze the relationships of various variables related with energy consumption in the transportation sector, and the data at the

end-use level such as vehicle usage, the number of vehicles according to the types of fuel used, fuel consumption, and income distribution of the population. This is a good start for predicting the future energy demand.

For prediction of end-use data, computer programs are often developed. In this study, a program is developed by using MATLAB SCILAB software. The program has two main components: database set and energy consumption prediction set.

2. Development of Energy Consumption Models at the User Level

For forecasting energy consumption requirements (E_D, ktoe), at the user level in the land transport sector, the equation of [1] is applied. It considers the relationship of the number of vehicles (N, vehicle), the average usage distance (S, km), and fuel consumption (F, l/vehicle-km). In order to forecast the energy demand, we classified the fuel consumption of vehicles in to 3 different cases as follows: 1) by usage area (Bangkok, Rural), 2) by the use of fuel types (gasoline, diesel, LPG and CNG), and 3) by vehicle type (private car which no more than 7 people (sedan), private car which more than 7 people (microbus & passenger van), private van and pick up, motor tricycle, urban taxi, fixed route taxi, motor tricycle taxi, business taxi, motorcycles, tractor, fixed route bus, non fixed route bus, private bus, small rural bus, non fixed route truck, private truck, and etc.)

Considering the above conditions, the model we developed can be written as equation 1.

$$E_D = \sum_{i=1}^{2}\sum_{j=1}^{4}\sum_{k=1}^{17} N_{i,j,k} \times S_{i,k} \times F_{i,j,k} \qquad (1)$$

Where i represents the usage area, j represents the fuel type, and k represents the type of vehicle. The number of vehicles ($N_{i,j,k}$, vehicle) in equation (1) is related to the gross domestic product (GDP, million), forecasting period (T = 1 In the year 2006), and the population (POP, person) as given in equation 2 [1].

$$N_{i,j,k} = e^{a} \times GDP^{b} \times e^{(rT)} \times POP \qquad (2)$$

The symbols a, b, and c represent the coefficients that are constant in the model. The equations 1 and 2 were implemented as a set of programs. The program set has 4 steps: Step 1 (Program 1), as part of the calculation of the constant (a, b, and c) of the model, Step 2 (Program 2) is part of calculation of the forecast of the number of vehicles in the future, Step 3 (Program 3) is the part of calculation of fuel demand forecast, and Step 4 (Program 4) is the data display section. The program structure is shown in Figure 1. In the development of the program, we used images at the user interface (Graphic User Interface, GUI) to allow users to learn and use the program more easily. The user interface is shown in Figure 2.

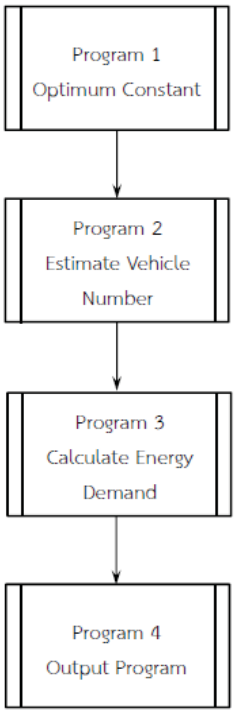

Figure 1 Program structure

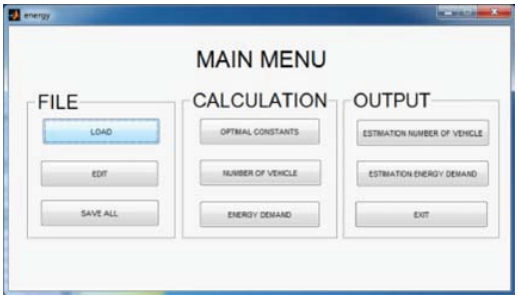

Figure 2 The user interface of "Main Menu"

The main menu of the program consists of three parts: 1) FILE: importing parts or customizing the base data, 2) CALCULATION: the calculation of various values, including the calculation of the model constants, forecasting the number of vehicles, and the fuel demand forecasting, and 3) OUTPUT: part of the data display.

3. Base Data Set

Data is needed for calculating the energy consumption such as average fuel consumption rate, the number of registered vehicles, gross domestic product, population size, and the average travel distance per year. The data is collected by searching websites, government agencies, and various reports. Part of data collected from a field survey is shown in Table 1 - 4.

Table 1 Average Fuel Consumption [1]

Vehicle Type	Average Fuel Economy (liter/ vehicle-100 kilometer) Bangkok area			
	Gasoline	Diesel	LPG	CNG
Sedan	8.569	8.0257	10.3515	9.3432
Microbus & SUVs	8.1235	7.2202	9.8134	9.8546
Van & Pick Up	8.0515	7.326	9.7254	8.7761
Motor tricycle	8.3333	7.2907	7.1429	9.0833
Urban Taxi	8.5985	7.5227	10.3872	9.3724
Fixed Route Taxi	7.6923	6.7299	9.2925	8.3846
Motor tricycle Taxi	8	6.9961	8.7184	8.72
Business Taxi	8.5985	7.5227	8.5985	9.3721
Motorcycle	4.075	-	-	-
Tractor	-	13.5612	-	-
Fixed Route Bus	-	9.1659	12.6586	9.3663
Non Fixed Route Bus	-	9.5877	13.2409	9.4914
Private Bus	-	9.542	13.1777	9.4501
Small Rural Bus	-	-	-	-
Non Fixed Route Truck	-	10.8696	-	11.1073
Private Truck	-	12.5628	-	12.8375
Others	7.2362	6.3492		7.1429

Vehicle Type	Average Fuel Economy (liter/ vehicle-100 kilometer) Provincial area			
	Gasoline	Diesel	LPG	CNG
Sedan	8.7336	8.1235	10	-
Microbus & SUVs	8.3195	8.244	10.0501	-
Van & Pick Up	8.7413	8.2305	10	-
Motor tricycle	8.3333	7.2907	7.1429	-
Urban Taxi	8.5985	7.5227	8.5985	-
Fixed Route Taxi	7.6923	6.5667	9.2925	-
Motor tricycle Taxi	5.685	6.9736	8.7184	-
Business Taxi	8.5985	7.5227	8.5985	
Motorcycle	4.7551	-	-	-
Tractor	-	13.5612	-	-
Fixed Route Bus	-	9.1659	12.6586	-
Non Fixed Route Bus	-	9.5877	13.2409	-
Private Bus	-	9.542	13.1777	-
Small Rural Bus	-	10.3199	14.3102	-
Non Fixed Route Truck	-	10.8696	-	-
Private Truck	-	12.5628	-	-
Others	7.2362	6.3492	-	-

Table 2 Number of Registered Vehicles (all 17 types) [2]

No.	Vehicle Type	Area	Fuel Type	2006	2007	2008	2009
1	Sedan (รถ1)	Bangkok	Gasoline	1618115	1644772	1587691	1307906
			Diesel	259445	305313	350604	297495
			LPG	25631	54703	255298	514687
			CNG	59	67	101	96
		Provincial	Gasoline	1253701	1395611	1509647	1618704
			Diesel	370610	496449	642205	716918
			LPG	13957	42965	220317	246047
			CNG	30	43	79	103
2	Microbus & Passenger Van (รถ2)	Bangkok	Gasoline	24999	23168	20669	19351
			Diesel	140264	134009	126784	120528
			LPG	425	909	5571	6171
			CNG	3	4	8	20
		Provincial	Gasoline	17847	17927	16820	16726
			Diesel	184118	199132	210516	221316
			LPG	419	1018	5119	6296
			CNG	4	6	13	20
3	Van & Pick Up (รถ3)	Bangkok	Gasoline	53897	49074	39227	37734
			Diesel	1005828	1056849	1004360	969693
			LPG	1376	3897	20930	22999
			CNG	7	12	124	638
		Provincial	Gasoline	235347	239137	229510	223729
			Diesel	3093127	3523610	3827820	4130042
			LPG	1440	7164	32854	99259
			CNG	2	11	79	322

No.	Vehicle Type	Area	Fuel Type	2010	2011	2012
1	Sedan (รถ1)	Bangkok	Gasoline	1586454	1689261	1704064
			Diesel	378597	420271	464149
			LPG	285627	354821	381804
			CNG	113	111	89
		Provincial	Gasoline	1807321	2024317	2251934
			Diesel	849088	1004878	1184974
			LPG	318265	419478	498910
			CNG	122	136	125
2	Microbus & Passenger Van (รถ2)	Bangkok	Gasoline	19131	19218	17653
			Diesel	122357	127575	125141
			LPG	7750	8589	9745
			CNG	30	60	67
		Provincial	Gasoline	16666	16213	15828
			Diesel	233662	244192	252930
			LPG	8151	10396	12516
			CNG	32	72	91
3	Van & Pick Up (รถ3)	Bangkok	Gasoline	35416	33257	33543
			Diesel	937867	961818	911741
			LPG	27215	37250	46440
			CNG	2879	3161	5579
		Provincial	Gasoline	215605	211560	201811
			Diesel	4358894	4672723	4889090
			LPG	49055	66549	95944
			CNG	3353	4286	7883

Table 3 Gross Domestic Product and Population [3]

GDP and POP Data		Year	Year	Year	Year
No.	Type	2006	2007	2008	2009
1	Gross Domestic Product, GDP (Million Baht)	7,844,939	8,525,197	9,080,466	9,041,551
2	Population (Person)	62,828,706	63,038,247	63,389,730	63,525,062

GDP and POP Data		Year	Year	Year
No.	Type	2010	2011	2012
1	Gross Domestic Product, GDP (Million Baht)	10,104,821	10,540,134	11,375,349
2	Population (Person)	63,878,267	64,076,033	64456695

Table 4 Average Travel Distance per Year *

Vehicle Type	Bangkok	Rural
Sedan	19,630.45	18,131.58
Microbus & Passenger Van	23,431.07	28,087.67
Van & Pick Up	19,145.85	23,943.96
Motor Tricycle	15,170.18	17,093.66
Urban Taxi	54,391.38	63,592.51
Fixed Route Taxi	21,537.96	20,681.12
Motor tricycle Taxi	28,457.07	16,853.16
Business Taxi	21,484.98	19,891.78
Motorcycle	6,328.13	6,393.65
Tractor	0	0
Fixed Route Bus	62,466.24	60,928.04
Non Fixed Route Bus	43,601.90	35,457.47
Private Bus	33,421.90	31,769.60
Small Rural Bus	0	47,759.90
Non Fixed Route Truck	34,345.91	74,040.51
Private Truck	33,852.96	62,656.87
Others	11,723.97	12,139.51

*From Field Survey

4. Results of the Model

The predicted results obtained from our model program was compared with the actual data in the past. We also compared the forecast results with the results from previous research by J. Pongthanaisawan et al [1]. The comparisons are shown in Table 5 and 6.

Table 5 Comparison of the Number of Vehicles Calculated from the Model with Actual Data and the Results of Previous Research

Total Number of Vehicle (unit)			
Year	Actual	Reference [1]	Model
2006	20,798,210		21,120,893
2007	22,256,971		22,423,187
2008	23,731,614		23,742,696
2009	24,604,117		25,052,366
2010	26,108,840	30,654,653	26,360,064
2011	28,129,467		27,674,080
2012	29,424,329		29,001,044
2013			30,346,184
2014			31,713,726
2015		36,390,540	33,107,183
2016			34,529,567
2017			35,983,527
2018			37,471,445
2019			38,995,509
2020		42,609,287	40,557,758

The forecast number of vehicles is compared with the actual data (during the years 2006 - 2012) in Table 5. The calculated results from the model are very close to the real data. The average difference between the calculated and actual data is only about 0.4 percent. The forecast in year 2010 was slightly higher than the actual data and is more accurate than the forecast of J. Pongthanaisawan et al [1]. The forecasts in year 2015 and 2020 are lower than J. Pongthanaisawan et al [1] with a difference of 3 and 0.05 percent respectively.

Table 6 Comparison of the Amount of Fuel Calculated from the Model with Actual Data and the Results of Previous Research

Total Energy Demand (ktoe)			
Year	Actual	Reference [1]	Model
2006	21,793		18666
2007	22,445		20130
2008	22,090		21488
2009	23,563		22776
2010	23,847	24,627	24029
2011	25,118		25271
2012	27,158		26517
2013			27779
2014			29063
2015		29,150	30378
2016			31728
2017			33117
2018			34550
2019			36030
2020		34,386	37560

Calculated fuel consumption forecasts by the model and actual data are compared in Table 6. The results from the model were found to be lower than the actual data with an average difference of about 13 percent and the predictions of previous research for the year 2010 showed that the values were close to the actual data. For the calculated fuel consumption from the model being lower than the actual data since the amount of fuel actually sold in all countries, in Thailand as well, includes some parts that are not used for transportation vehicles on the road and might be used in agriculture or other forms of transportation. For the forecast period, which is from the year 2010 onwards, the forecast results of the model are compared to the results of the previous three years of research: 2010, 2015, and 2020. It was found that the values to be more similar when the forecast period was longer, with a difference of 13, 7 and 2 percent respectively.

5. Conclusion

The forecast of number of vehicles obtained from the developed model is close to both the actual data and the results from J. Pongthanaisawan et al [1]. For the amount of fuel, it was found that the results from the model were reasonable when compared to the actual data. However, the values obtained in the predicted calculations were slightly less than the actual values. The amount of fuel data actually contained the use of fuel in areas other than the use of vehicles on the road. Therefore, the actual amount of fuel sold must be higher than the amount used by the road vehicles. It was concluded that the developed model was reasonable and reliable to be used as a guideline for predicting the energy consumption forecasts at the user level. As future research, we plan to collect recent data and update our model if needed.

References

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