Fuel Station Capacity on Major Arterial Road in Thailand: A Case Study in Chonburi Province, Thailand

Supornchai Utainarumol and Surachai Ampawasuvan

***Abstract*—Fuel Service Station is an important activity that is located along the side arterial road with traffic a lot of throughout all the day. However, traffic volume entrance more than fuel station capacity, and then generate queue length on Main Street. The cause traffic jams at the entrance – exit fuel station on Main Street. That is reason studied behavior of fuel station capacity, and that does not cause queuing spill out onto the main street to cause traffic impact problems. This analysis important third variables include number of dispenser, parking space and queue length from setback right of way to dispenser. This studied by queuing micro-simulation, polynomial regression and linear regression, which found number of dispenser is affect important variable with capacity of fuel station. The parking space variable is moderate affect capacity of gasoline station, that difference of Liquid petroleum gas station. There have queue length affect moderate variable with capacity of fuel station. These results led to the better traffic management planning within the fuel station area by type of fuel station.**

***Index Terms*—Fuel station, queue length, arterial road.**

I. Introduction

The most traffic jam of them consists of road capacity and intersection caused by the trip generation to carry out activities along the road. It causes delays and inconvenience from the access point. Sometimes, queue lengths of the traffic volume can enter the activity area. It causes delays and inconvenience from the access point, which has queue lengths of the traffic volume enter to the side road activity area [1].

The most of universal requirements for Traffic Impact Assessment (TIA) is recommend for that result in entrance - exit activity area more than 100 trips per hour or activity area size and location site. [2]-[3] The set relief measure reduces traffic impact on road users has Internal traffic management and External Infrastructure management. [4]-[5].

Fuel station is an activity that a vehicle requires. Either for refueling or other activities within the fuel service stations that have a variety of activities.[6]-[8] This is a side road activity that needs to travel to and out of large areas. Especially fuel stations located along the major arterial road, most of which travel through traffic with high speed and controlled access for the safety of road users.

That is preventing the effect of waiting for a service that can affect the queue length that overflows into the major arterial road, which will affect traffic flow on the main road. It is necessary to study the capacity of fuel stations along major arterial road, which can accommodate the entrance trip to fuel station without causing queue length overflow to main road. This used for traffic planning for internal traffic managements in accordance with traffic impact preventive measures.

Manuscript received October 30, 2017; revised March 12, 2018.

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II. Scope Study

The study fuel service station located on the major arterial road in Chonburi province. It is divided into 3 types of fuel stations:

- Gasoline & Diesel Station (Oil)
- Liquid Petroleum Gas Station (LPG)
- Compressed Natural Gas Station (CNG)

The variables used in the analysis consisted of 3 variables:

- Number of dispensers in fuel station
- Queue length space in fuel station
- Number of parking spaces in fuel station

Definition: The capacity of a fuel station service means the ability to the maximum traffic demand entrance to station, and then has not queue length over flow to Main Street.

III. Methodology

This study is divided into 4 steps, including the first steps to field data survey, and secondary steps to Queuing Simulation model. The third steps to amount of trip into the fuel station from the regression model. Final steps to create a linear regression of the capacity of the fuel service station, then consist to independents variable from the dispenser, parking, and queue length. As shown in Fig. 1.

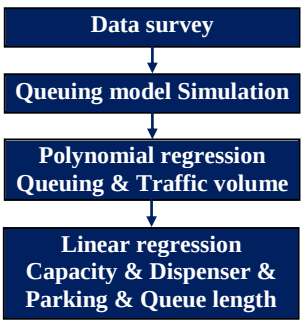


Fig. 1. Step of study.

DOI: 10.7763/IJET.2018.V10.1085

A. Field Survey

It consists of a survey of the service period of the customer and the Behavior within the fuel service station.

Re-fuel time in fuel station

Period time of other activity service within the fuel station

Behavior after Re-fuel service (Go-out or choose other service)

Behavior and Time of waiting Re-fuel service

Type of vehicle service

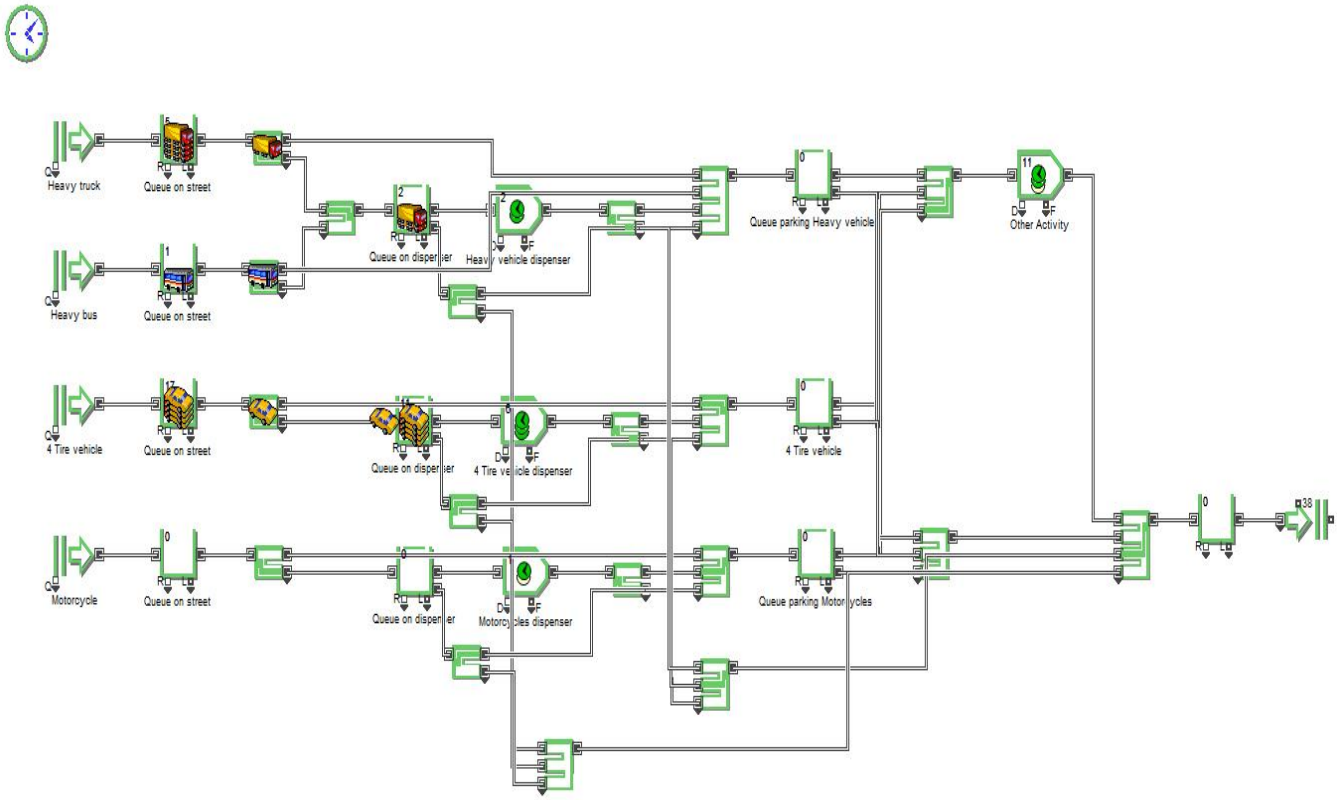


Fig. 2. Fuel station queuing simulation (Extend Sim).

There are 4 categories of vehicles used in the service.

GROUP 1. General car: 4-wheel (4 Tires) consists of passenger car less than 7 seats and more than 7 seats (Passenger Car, PC <7 / PC> 7), Light bus (LB) and light truck (LT)

GROUP 2. Heavy buses include 2 – 3 Axle vehicle (6-12 Tires) consisting of medium buses (MB) and heavy bus (HB).

GROUP 3. Heavy trucks include more than 2 – 3 Axles (6 Tires up) consisting of median trucks (MT), Heavy truck (HT), Tailor (Tr) and Semi-Tailor (Semi-Tr)

GROUP 4. Motorcycle

As shown in Table I.

TABLE I: VEHICLE GROUP

Group	1	2	3	4
PCE factor	1.00	2.10	2.50	0.33
Type	General car	Heavy bus	Heavy Truck	Motorcycle
Vehicle Type	PC<7 PC>7 LB LT	MB HB	MT HT Tr Semi Tr	MC
Detail	4 Tires	6 – 12 Tires	6 Tires Up	2 Tires

B. Queuing Model Analysis

Queuing simulation model by Extend Sim program to the study service behavior. The model is calibrated to the actual state of the data survey, with a model. As shown in Fig. 2.

Model analysis finds out the queue length from the fuel station to the main street.

It is varying the traffic volume to the fuel station starting from 50 vehicles per hour to 1,000 vehicles per hour. (50, 100, 200, 500, and 1,000 Veh/hr). Which depending on the type and characteristics of the fuel station, as shown in Table II.

TABLE II: FUEL STATION CHARACTERISTIC MODEL

Type	LPG	CNG	OIL
Heavy vehicle dispenser	-	8	4
4 Tires vehicle dispenser	12	8	6
Motorcycle dispenser	-	-	2
Model total dispenser	12	16	12
Model Parking	60	80	25

C. Relationship of Queuing Analysis

Creating the relationship of the length of the queue length overflows from fuel stations to Main Street with entrance traffic demand into fuel station.

That is polynomial regression characteristic. The data

obtained from queuing model simulation with the form shown in (1)

$$Y = aX^2 + bX + C \quad (1)$$

Y = Queue length on main street (PCU)
X = Arrival rate (Vehicle/hour)
a = Coefficient 1
b = Coefficient 2
c = Constant

This analysis predicts the amount of traffic entrance demand volume to the fuel station. That does not queue length overflows onto Main Street.

D. Capacity Analysis

The linear regression equation of fuel stations capacity with number of dispenser, parking space area and queue length for setback right of way to dispenser. That using data from queuing equation (1) in the relationship of the long queue length overflows from fuel stations onto Main Street.

There it with on the amount of travel entrance traffic demand volume into the service station with characteristic of fuel stations.

The correlation analyzing coefficients of variables is relationship between variables of 4 variables that will be used to build regression model analysis is formed by the equation shown in (2)

$$r = (nnXY - nXnY) / (ennX^2 - nX^2 * ennY^2 - nY^2) \quad (2)$$

r = Pearson correlation, r
X = Variable 1
Y = Variable 2
n = Number of Variables

The correlation coefficient is a value that indicates a relationship between variables. The relationships of the variables shown in Table III

TABLE III: LEVEL OF RELATIONSHIP

Correlation, r	Level of Relationship
0.90 – 1.00	Very high
0.70 – 0.90	High
0.50 – 0.70	Medium
0.30 – 0.50	Low
0.00 – 0.30	Very low

Remark: Hinkle D.E. 1998, p.118

Linear Regression in this study determines dependent variable is the capacity of the fuel stations capacity with independent variables form equations. As shown in (3)

$$Y = aX_1 + bX_2 + cX_3 + d \quad (3)$$

Y = Capacity of fuel station
(Vehicle per hour)
X_1= Dispenser number (dispenser)
X_2 = Parking space (vehicle)
X_3 = Queue length space (vehicle)
X_3 = 1 + (L/6.00)
L= right of way to dispenser
a = Coefficient X_1
b = Coefficient X_2
c = Coefficient X_3
d = Constant

IV. RESULT

The field survey in fuel station major arterial road gathers information on field length of service refuel and duration of other service activities within fuel station find that general car (4 Tires) refuel oil filling between 1minute and 56 seconds to 2 minutes and 50 seconds per vehicle less than the fill gas takes to fill 3 minutes 49 seconds to 5 minutes and 7 seconds.

Heavy bus and heavy truck find time to refuel between fuel oil as gas. It has time to fill between 13 minutes and 16 seconds to 18 minutes and 53 seconds.

Finally, motorcycle found refuel around 51 seconds and or a period of service other activity between 4 minutes and 13 seconds to 6 minutes and 7 seconds, that most customer use fuel station by oil fuel more than fuel station by gas. Show in Table IV.

TABLE IV: SERVICE TIME OF VEHICLE REFUEL

Type	**General car**	**Heavy bus**	**Heavy Truck**	**Motor cycle**	**Other Activity**
LPG	3.49	None	None	None	0:04:22
CNG	5.07	17.08	13.16	None	0:04:56
Oil diesel	2.50	18.53	14.41	None	
Oil gasoline	1.56	None	None	0.51	
Average Oil	2.31	18.53	14.41	0.51	0:06:07

Remark: Unit minute per vehicle

The proportion of vehicle type service divided by the last working day found the most general car around 75.79 to 91.66 percent.

Liquid petroleum gas service station has most general car customer service bus heavy bus and heavy truck does not service it. The heavy vehicle to use particular service to oil and natural compression gas (CNG or NGV) station service around 0.49 to 10.33 percent.

Finally, motorcycle segment to use the oil service station fuel around 12.94 to 14.56 percent, as shown in Table V

TABLE V: PERCENT OF VEHICLE TYPE SERVICE

Type	General car	Heavy bus	Heavy Truck	Motor cycle
LPG weekday	87.68	0.10	3.10	8.57
LPG weekend	91.66	0.02	0.82	7.47
CNG weekday	75.79	1.87	10.33	4.81
CNG weekend	80.56	1.59	6.43	2.43
Oil weekday	79.31	1.05	4.58	14.56
Oil weekend	83.47	0.49	2.97	12.94

TABLE VI: PROPORTIONS OF VEHICLE REFUEL

Type	General car	Heavy bus	Heavy Truck	Motor cycle
LPG	0.95	0.00	0.00	0.00
CNG	0.90	0.98	0.95	0.00
Oil diesel	0.67	0.05	0.95	0.00
Oil gasoline	0.59	0.00	0.00	0.95
Average Oil	0.64	0.05	0.05	0.95

The most purpose of customer service need refuels in to gas service station around 90 percent more than oil service station.

The general car to use refuels around 64 percent by oil service station, but motorcycle need refuel more than 95 percent. Shown in Table VI

A survey in the field of customer service behavior to after the service refueling found that most are getting out of the service fuel station immediately after more than 94 percent without the use of other services within the station, that except gas service stations has the general car will use other activity services within after refueling station was completed before leaving the fuel station approximately 40 to 45 percent. Show in Table VII.

TABLE VII: PROPORTIONS OF RUN OUT AFTER REFUEL

Type	General car	Heavy bus	Heavy Truck	Motor cycle
LPG	0.60	None	None	None
CNG	0.55	0.95	0.70	None
Oil diesel	0.93	0.95	0.95	None
Oil gasoline	0.95	None	None	0.94
Average Oil	0.94	0.95	0.95	0.94

The result of customer fuel station survey in maximum waiting time of refuel allowable found general car to waiting between 3 minutes and 40 seconds to 14 minutes 32 seconds, then heavy bus and heavy truck to wait between 10 minutes 33 seconds to 20 minutes.

Finally, motorcycle has maximum waiting time around 3 minutes 26 seconds.

The most of heavy vehicle has waiting time of refuel service more than light vehicle. Show in table VIII

TABLE VIII: MAXIMUM WAITING TIME SERVICE

Type	General car	Heavy bus	Heavy Truck	Motor cycle
LPG	0:05:24	N/A	N/A	N/A
CNG	0:14:32	0:15:00	0:20:00	N/A
Average Oil	0:03:40	0:10:33	0:10:33	0:03:26
Other Activity	0:05:00	0:10:00	0:10:00	0:02:00

Remark: Unit in minute per vehicle

The average service time on the amount of traffic arrival demand into the fuel station found that oil service station fuel oil has customer use minimal duration (9 minutes and 41 seconds).

It has arrival demand into the service station as possible well as a variety of vehicle types that use the service more gas service station stations than double arrival demand of oil service station. Show in Table IX.

TABLE IX: TOTAL TIME SERVICE IN FUEL STATION

Type	Total time service (Minute / Vehicle)	Flow rate (Vehicle / hour)
LPG	0:12:29	96.17
CNG	0:14:18	81.83
OIL	0:09:41	198.67

The calibration queuing model from micro simulation with actual in field survey found movement between 0.15 to 7.41 percent, which high confidential expected to be established. Shown in Table X.

TABLE X: VALIDATION OF SIMULATION MODEL

Type	Field		Model		Error	
	Trips attraction (Veh/hr)	Trip production (Veh/hr)	Trips attraction (Veh/hr)	Trip production (Veh/hr)	Trips attraction (%)	Trip production (%)
Gasoline	212	191	209	191	1.57	0.15
LPG	96	80	91	85	5.87	5.91
CNG	101	77	99	83	2.79	7.41

The result analysis of relationship between the queue length overflow onto Main Street with traffic arrival rate entrance fuel station fuel find polynomial curve characteristic relations.

The queue length is multiplied by the amount of traffic volume into the fuel station, which varies according to the type of service. Shown in Fig. 3.

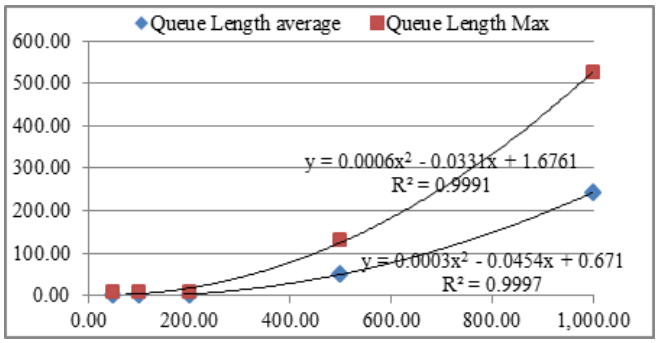


Fig. 3. Relationship of queue length with traffic demand.

The result of polynomial regression equation relations between queue length with traffic arrival demand into fuel station to testing correlation of variables found number of dispenser has high relationship with fuel station capacity in gas service station (r = 0.6797 – 0.9453) and moderate relationship for oil service station. The compression natural gas service station is capacity highly effect to number of dispenser. Oil service station has parking space and number of dispenser to moderate relationship with capacity, that different to liquid petroleum gas service. It has number of dispenser to highly relationship and queue length to moderate relationship with capacity. Show in Table XII.

TABLE XI: CORRELATION TEST OF VARIABLES

		Fuel station weekday				Fuel station weekend			
		Dispenser number	Parking space	Queue length space	Capacity	Dispenser number	Parking space	Queue length space	Capacity
Gasoline station	Dispenser number	1.0000				1.0000			
	Parking space	0.0000	1.0000			0.0516	1.0000		
	Queue length	0.0000	0.0000	1.0000		-0.0076	-0.0566	1.0000	
	Capacity station	0.4988	0.4798	0.2136	1.0000	0.1275	0.4283	0.3518	1.0000
LPG station	Dispenser number	1.0000				1.0000			
	Parking space	0.0000	1.0000			0.0000	1.0000		
	Queue length	0.0000	0.0000	1.0000		0.0000	0.0000	1.0000	
	Capacity station	0.7850	-0.0741	0.4450	1.0000	0.6797	-0.0311	0.5387	1.0000
CNG station	Dispenser number	1.0000				1.0000			
	Parking space	0.0000	1.0000			0.0255	1.0000		
	Queue length	0.0000	0.0000	1.0000		0.0452	-0.0633	1.0000	
	Capacity station	0.8908	0.0949	0.1874	1.0000	0.9453	0.0521	0.2274	1.0000

The linear regression of fuel station capacity create 3 variables include the number of dispensing fuel, parking space inside the station and setback of right of way to dispenser (queue length space) found a gas service station with a confidence level more than oil over service station.

The compressed natural gas stations (CNG or NGV) have a high confidence level (R-square = 0.837- 0.929), more than petroleum liquids service station with a confidence level is relatively high (R-square = 0.753 - 0.819)

Finally, oil service station has moderate confidence level (R-square = 0.337- 0.525). Shown in table XII

TABLE XII: FUEL STATION CAPACITY LINEAR REGRESSION

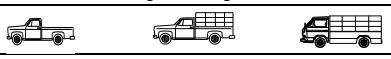
	Dispenser number (a)	Parking Space (b)	Queue length space (c)	Constant (d)	R-square
Gasoline fuel station working day	10.2245	2.6024	35.3889	-10.9467	0.5246
Gasoline fuel station weekend	2.1779	2.4140	61.5960	22.9520	0.3369
LPG fuel station working day	53.3452	-0.5036	92.3889	-482.4365	0.8198
LPG fuel station weekend	43.8254	-0.2008	106.1111	-477.4868	0.7531
CNG fuel station working day	22.9669	0.6671	40.2222	-270.4587	0.8377
CNG fuel station weekend	19.6930	0.2506	34.6089	-213.8076	0.9294

V. CONCLUSION

This studies of fuel station at a specific location on the major arterial road with the services provided by the operator only. The capacity of the fuel stations may be reduced by the amount of time on refuel and service station customer behavior of the type of vehicle used in the area. Mathematical equations of study can be used for applications in the primary planning stages of the supply management of fuel station. Gas station need setback dispenser to right of way more than oil station, then because refuel gas is more than three time with as oil and most heavy vehicle choose gas for fuel. That will affect the capacity of the station is quite a lot, then need special consideration. The oil station must be considered in the parking space in the analysis. This preliminary conclusion is used to analyze the traffic impact assessment for fuel station along major arterial road.

APPENDIX A

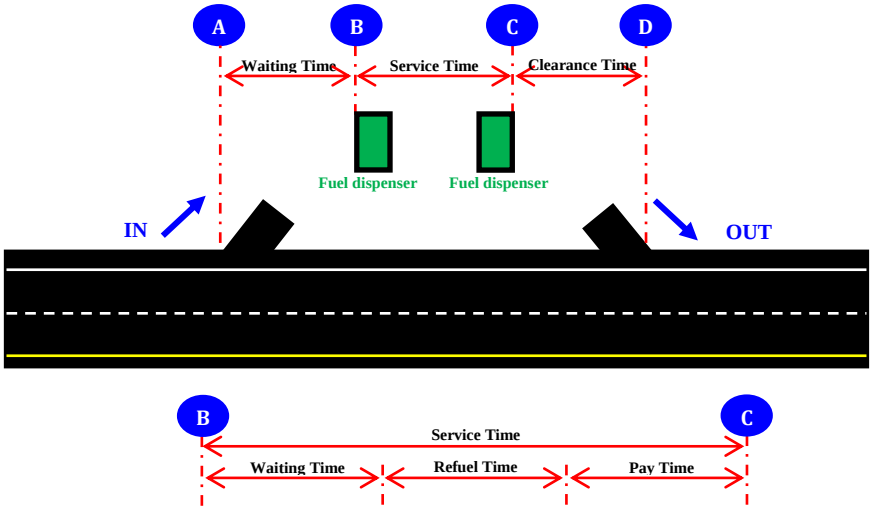
A. Vehicle Classification

Type		Axle	Tire	Symbol
PC<7	Passenger car under 7 seat	2	4	
PC>7	Passenger car over 7 seat	2	4	
LB	Light bus	2	4	
MB	Medium bus	2	6	
HB	Heavy bus	2 – 3	6 – 12	
LT	Light truck	2	4	
MT	Medium truck	2	6	
HT	Heavy truck	3 – 4	10 – 12	
Tr	Full Trailer	5 – 8	14 – 28	
Semi-Tr	Semi-Trailer	5 – 7	18 – 24	
MC	Motorcycle	2	2	

Remark: Resource by Thailand Department of Highways [9]

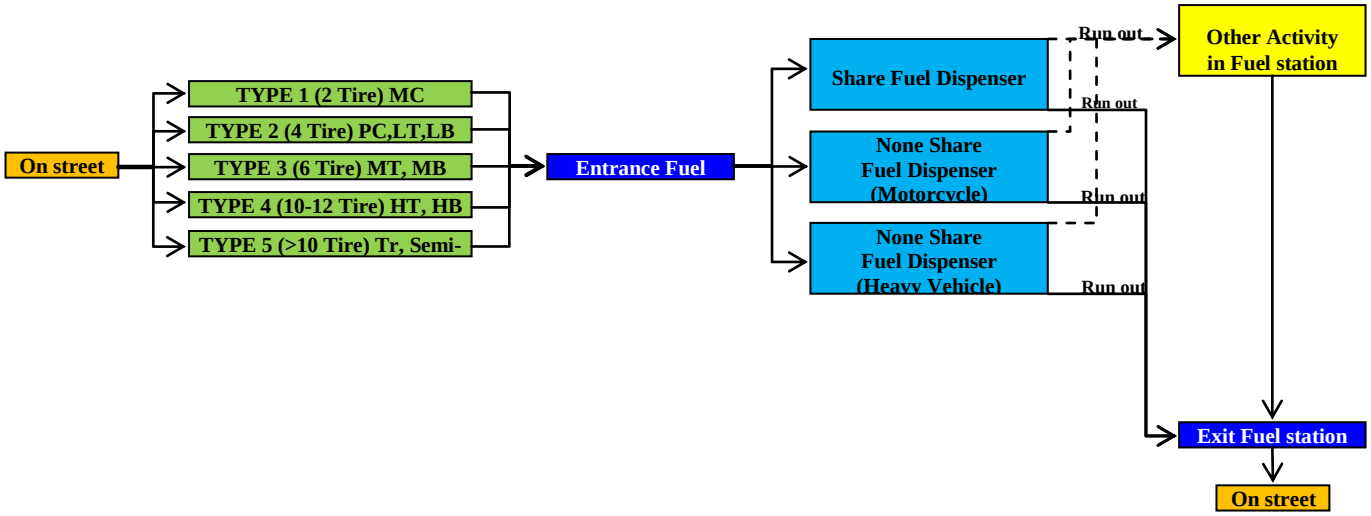
APPENDIX B

A. Fuel Time Service System



APPENDIX C

B. Fuel Service Model



ACKNOWLEDGMENT

This work was performed with the help and cooperation from the customers in fuel station on Route number 344 Chonburi - Banbung and Route number 361 by pass Chonburi in providing data to the research team. Besides, the cooperation and help is from officials of the Chonburi Highway District of Thailand Department of Highways. The authors would also like express the appreciation to the reviewers for their comments and guidance.

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