The Comparative Evaluation of the Cost of Traveling and Environment on the Expressway Route vs. the Ground Level Road in Bangkok

Review of Integrative Business & Economics Research

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ABSTRACT

This study aims to evaluate four travel-related benefits which are (1) riding quality, (2) savings on fuel consumption and travel time, (3) reducing of vehicle emission and (4) traffic safety. These types of traffic information influence travel planning and route choice decision and also help traffic manager to regulate traffic flow in a specified network by providing the information to travelers. To achieve this evaluation, Intelligent Transport Systems (ITS) are one of the limited responses remaining to reducing traffic congestion in conjunction with collecting traffic data. Global Positioning System (GPS) was adapted for data collection on an elevated expressway and alternative road. Six probe vehicles were equipped with GPS and data-logger to gather second-by-second travel data such as speed, time and location. Besides of riding quality and traffic safety, the paper also examined travel time and distance trajectories and driving cycle to estimate instantaneous fuel consumption and pollutant emissions. The findings and discussions were also reported in this paper

Keywords: GPS, Fuel Consumption/Emission Model, Riding Quality, Traffic Safety

1. Introduction

The Expressway Authority of Thailand (EXAT) has been managing the Bangkok's expressway system of approximately 208 kilometers with 1.3 million trips per day of which steadily increases. Methods of transport management system play a vital role in reducing traffic congestion situations. Intelligent transport systems (ITS) are one of the limited responses remaining to help those congestion problems. In this study, Global Positioning System (GPS) was adapted for data collection on an elevated expressway and parallel Road Ground Level. The collected GPS data sets include travel time, travel distance and driving pattern replicated traffic conditions on the elevated expressway and the Road Ground Levels. These were used to determine four issues of travel-related benefits including (1) riding quality, (2) savings on fuel consumption and travel time, (3) reducing of vehicle emission and (4) traffic safety.

2. Objectives

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The study aims to collect travel data on the expressway and parallel routes using GPS technique. The data will be used to develop SIDRA-TRIP integrated GPS model to estimate fuel consumption and emission pollutants on the expressway system and parallel route. Travel time, indicator of traffic safety and riding quality of the comparative route are also considered. The results obtained from this study will be provided to expressway users to promote the use of expressway system.

3. Tested Routes

This paper focuses on a parallel routes; one is an elevated expressway route while the other is an at-grade route. The selected routes have the same origin-destination, a number of lanes as well as travel distance. More importantly, they are major road linking the North-Eastern of Bangkok to CBD and face on congestion problem during peak hours. The data collection was conducted on weekday during AM peak period. Figure 1 describes the tested routes. The elevated expressway route serves about 100,000 trips daily whereas the at-grade route has twice number of traffic volumes, and it is congested during peak periods.

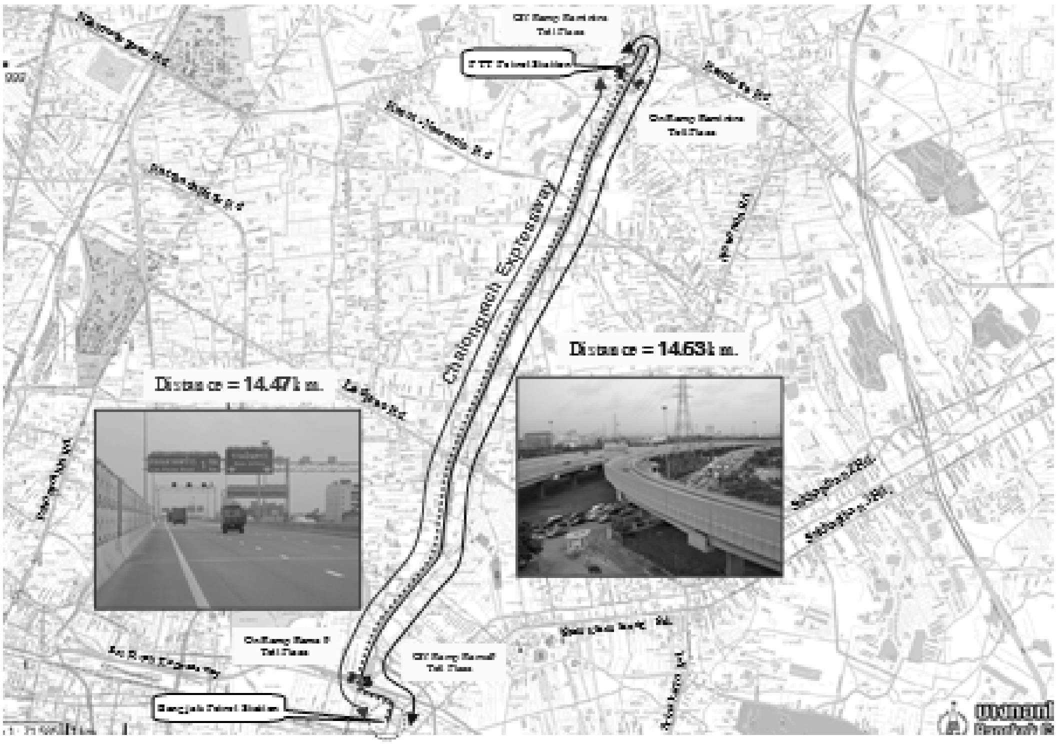

Figure 1 Selected routes: Elevated Ramindra-At-Narong Expressway and Opted Road Ground Level

4. Data Collection Approach

GPS with data logger was used to collect second-by-second traffic data. The tested vehicles were equipped with the GPS and data logger. A number of trips on both routes were made. Various data sets were then transferred to a workstation to be

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integrated with the SIDRA-TRIP software. A number of measures, e.g. travel time and distance trajectories, fuel consumption and pollutant emissions were then estimated. Detailed discussion of data collection made can be found in [1].

5. Four-Mode Elemental Fuel Consumption/Emission Models

The SIDRA-TRIP or four-model elemental model is based on drive cycles to estimate fuel consumption and pollutant emissions. The drive cycles come from the standard drive cycle or drive cycle data representing a series of traffic events which are specified in term of cruise, idle and speed change (acceleration or deceleration). The algorithm is based on the power-based model developed by [2] which relates instantaneous fuel consumption to the instantaneous power-based model is that it relates fuel consumption to the fundamentals of vehicle motion which is relatively easy to calibrate using an instrumented vehicle. In the model implementation in SIDRA-TRIP, emissions are calculated for Light (1,400 kg) and Heavy Vehicles (11,000 kg). Buses, trucks, semi-trailers (articulated vehicles), cars towing trailers or caravans, tractors and other slow-moving vehicles are classified as Heavy. All other vehicles are defined as Light Vehicles. These models have been calibrated and validated for Australian vehicles [3] and used in SIDRA-TRIP to estimate fuel consumption, CO_2, CO, HC, and NO_x. The model is used to estimate fuel consumption, pollutant emissions i.e. CO, CO_2, HC, NO_x. The main inputs to these models include driver behaviour attributes (vehicle speed and acceleration), vehicle characteristics (weight or mass) and road geometry (grade). For a general emission or consumption parameter, X, the following relationships (equations 1 and 2) are used [4]:

$$\frac{dE(X)}{dt} = \alpha + \beta_1 R_T v + \left[\frac{\beta_2 M a^2 v}{1000}\right]_{a>0} \qquad , R_T > 0 \tag{1}$$

$$\frac{dE(X)}{dt} = \alpha \qquad , R_T \le 0 \tag{2}$$

where E(x) is the rate of fuel consumption or emission, RT is the total tractive force required to drive the vehicle (equation 3), M is the vehicle mass (kg), α is the idling fuel consumption/emission rate, β1 is an engine efficiency parameter (mL or g per kJ) relating fuel consumption/emission to energy provided by the engine, β2 is a second efficiency parameter (mL or grams per $kJms^{-2}$) relating fuel consumption /emission during positive acceleration to the product of inertia and acceleration, v is the velocity (kph) and a is acceleration (mpss). RT can be computed according to equation (3) where g is the gravitational acceleration (ms^{-2}), G is the percent gradient, b1 is drag force parameter (rolling resistance) and b2 is drag force parameter (aerodynamic resistance). Figure 2 and Figure 3 show simulating outputs based on field data. These include distance, speed, acceleration and noise level.

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Figure 2 At-grate Road SIDRA-TRIP Model (Praditmanootham Rd.) Inbound (A.M. Peak, Workday)

Figure 3 Expressway SIDRA-TRIP Model (Ramindra-At-Narong Expressway) Inbound (A.M. Peak, Workday)

6. Travel and Environmental Costs

Travel costs of common trip makers are based on travel time cost and vehicle operating costs. The travel time cost depends on various factors of commuters whereas the vehicle operating costs include the obvious costs of fuel, oil and tyres, and an element of vehicle maintenance. For expressway users, toll is an additional

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cost of travel. These costs are known as generalised cost, and influence route choice decision. For this study, fuel and time costs are used as follows:

- Cost of fuel (Gasohol 95) is 42.05 Baht per Litre. This is based on oil price at Bangkok.
- Time cost of 77.84 Baht per PCU-Hr is applied.

Regarding environmental cost, a study made by the Victoria Transport Policy Institute, Australia [5] recommended environmental costs depending on each type of pollutant emissions. These are shown below:

- Cost of NOx is 15,419 US $/ton or 498.86 THB/kg
- Cost of CO is 435 US $/ton or 14.07 THB/kg
- Cost of HC is 0.0008 Euros/kg or 0.04 THB/kg
- Cost of CO2 is 18.13US $/ton or 0.59 THB/kg

In addition, it has been found that rate of pollutant emissions (CO, CO_2, HC, NO_x) is much higher during stop-and-go driving condition, for example, urban street driving condition [6] . Unlike, travelling at speed ranged from 60-80 kph produces a smaller amount of emission.

7. Analysis of Riding Quality

The study aims to determine the differences between taking expressway route and its ground level. One of indicators is riding quality of which the expressway users perceive during their journey. In this study, GPS speed data was used to determine speed category of those tested routes. The category represents traffic flow conditions. For instant, speed range of 0-20 kph can be identified as stop-and-go traffic condition whereas speed over 80 kph represents free-flowing traffic condition. As a result, it can be said that speed category is a function of riding quality.

Results of riding quality are presented in Figure 4. The expressway users could speed from 60-100 kph for their trip (about 35 percent) whereas the Road Ground Level users would face on traffic congestion and drove in stop-and-go condition. The results also indicate levels of driving condition or level of service indicating that the expressway system provides users with higher level of service or higher riding quality.

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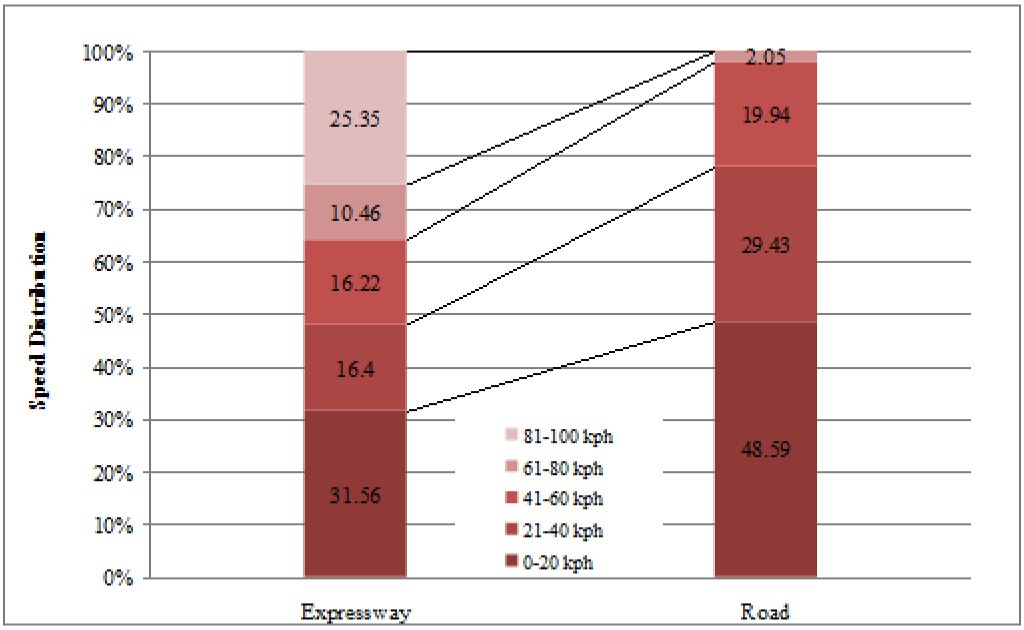

Figure 4 Analysis of Riding Quality: Speed Distribution

8. Analysis of Traffic Safety

This study also aims at determining level of traffic safety. GPS speed data was used to analysis acceleration rate and acceleration noise occurred during data collection period. This study uses the acceleration noise to represent probability of accident. Acceleration noise was first proposed by Herman et al (1959) [7] as a means to measure traffic conditions and driving behavior. Jones and Potts (1962) [8] tried to use this parameter to quantify road, driver, and traffic condition in Adelaide, Australia. The authors examined the effect of different roads, drivers, and traffic conditions on acceleration noise. The results showed that the acceleration noise was significantly greater on roads with more horizontal curvatures. In addition, the authors also explained that a road with multiple curves, which is more likely to cause a crash, tends to yield a greater acceleration noise. Details of discussion and findings can be also found in [9].

In this study, acceleration noise is used to identify level of traffic safety on the tested routes. Table 1 presents overall result of this investigation. It was found that average speed on the expressway is 73.42 kph (Max. speed 92.20 kph) with average acceleration of 0.05 mpss (S.D. 0.16). Conversely, the Road Ground Level performs average speed of 37.10 kph (Max. speed 63.70 kph) with average acceleration of -0.001 mpss (S.D. 0.47).

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Table 1 Descriptive Statistic

Descriptive Statistic	Expressway route		At-grade route	
	Speed (km/h)	Acceleration (m/s^2)	Speed (km/h)	Acceleration (m/s^2)
Mean	73.42	0.05	37.10	-0.001
Std. Deviation	25.32	0.16	19.31	0.47
Minimum	0	-0.42	0	-1.49
Maximum	92.20	0.53	63.70	1.22

Based on the findings, Standard Deviation or acceleration noise occurred on the expressway route was 0.16 whereas those occurred on the Road Ground Level was 0.47. It is obvious that acceleration noise found on the expressway route was three times lower than that happened on the alternative road. In addition, the paper estimates the probability of accident based on acceleration noise using Boonsiripant model [9]:

$$AccHC = L^{0.706\ e(2.2923+2.0295(AN\_Aj)} \quad (3)$$

Where L represents length of considered route, in meter while AN_Aj is acceleration noise. As a result, this investigation found that probability of crash on the expressway route is lower than that travelling on the at-grade route by 75 percent.

9. Results

Figure 5 and Table 2 show outputs travelling on the expressway against using the Road Ground Level. For inbound, it is obvious that using the elevated expressway saved travel time and fuel consumption by 43 percent (16 minutes) and 11.7 percent, respectively. Therefore, the travel cost saving is 29 THB per trip or 25 percent. It is interesting to note that pollutant emissions on the elevated expressway are also smaller than those for the Road Ground Level by 12-39 percent. For outbound, there is no significant difference in travel cost between the routes. however, the vehicles travelled on the expressway reached their destination sooner by 7 minutes or 24 percent, and produced a smaller rate of emission by 21-23 percent, as described in Table 2.

Regarding riding quality as shown in Figure 4, the expressway users could speed from 60-100 kph for their trip (about 35 percent) whereas the Road Ground Level users would face on traffic congestion and drive in stop-and-go condition. The findings also indicate that using expressway is safer by 75 percent.

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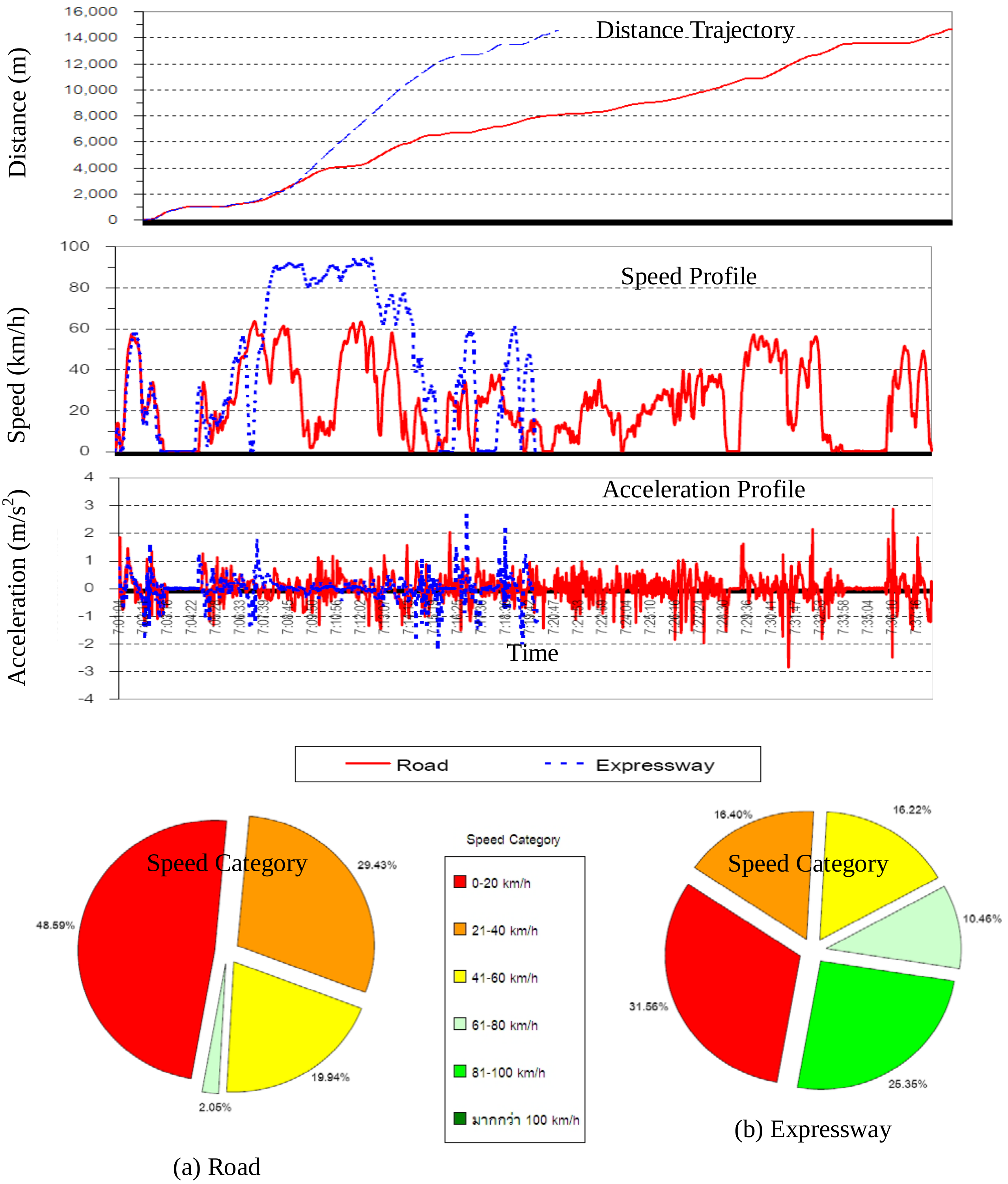

Figure 1 Distance Trajectory (Top) Speed Profile & Acceleration (Mid) and Speed Category (Bottom) of Road Ground Level and the Ramindra-At-Narong – Inbound direction (A.M. Peak, Weekday)

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Table 1 Fuel Consumption/Emission Results

	Road Ground Level (1)	Expressway (2)	% Diff. [(1) – (2)]100/(1)
<u>Inbound</u>			
Distance (km)	14.67	14.55	0.8
Total fuel consumption (litre)	1.57	1.39	11.7
Travel time (minute)	38.4	22.0	42.7
Rate of fuel consumption (km/litre)	9.37	10.51	-12.1
Travel costs			
Fuel (THB)	66	58	11.7
Time (THB)	50	29	42.7
Total travel costs (THB)	116	87	25.0
Avg. travel costs (THB/km)	7.90	5.98	24.3
Emission pollutants			
NOx (kg)	0.0058	0.0045	22.3
CO (kg)	0.1618	0.1232	23.9
HC (kg)	0.0062	0.0038	38.6
CO_2 (kg)	3.9272	3.4687	11.7
<u>Outbound</u>			
Distance (km)	15.25	15.32	-0.5
Total fuel consumption (litre)	1.50	1.62	-8.0
Travel time (minute)	30.0	22.8	24.0
Rate of fuel consumption (km/litre)	10.23	9.50	7.1
Travel costs			
Fuel (THB)	63	68	-8.0
Time (THB)	39	30	24.0
Total travel costs (THB)	102	98	4.2
Avg. travel costs (THB/km)	6.67	6.37	4.5
Emission pollutants			
NOx (kg)	0.0053	0.0042	21.3
CO (kg)	0.1438	0.1124	21.8
HC (kg)	0.0049	0.0038	22.9
CO_2 (kg)	3.7423	4.0412	-8.0

Remarks: (1) Fuel price of Gasohol 95 is 42.09 THB/L (PTT dated June 15, 2008)

(2) Value of time for passenger car is 77.84 THB/PCU-hr

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10. Conclusion

Besides of riding quality and safety, the paper also examined instant fuel consumption and pollutant emissions. Using the SIDRA-TRIP integrated with GPS technology enables the analysis of driving pattern on the selected routes. The technology itself and the capability of state-of-the-art fuel consumption/emission models (SIDRA-TRIP) allow traffic engineers to estimate travel time and distance trajectories of the tested vehicles as well as rates of fuel and emission pollutants. Based on this technique, it was found that stop-and-go conditions were often occurred at where Road Ground Level was selected. This situation was found to consume a higher rate of fuel and to produce a higher rate of emission. These results were similar to the study conducted by [6] and [10]. More comfortable and safer driving by 35-75 percent can be received by using the expressway system.

10. Acknowledgement

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