Journal of Physics:
Conference Series

PAPER • **OPEN ACCESS**

Efficient methodology of route selection for driving cycle development

To cite this article: A R Mahayadin *et al* 2017 *J. Phys.: Conf. Ser.* **908** 012082

Efficient methodology of route selection for driving cycle development

A R Mahayadin[1,2], Shahriman A B[1,2], M S M Hashim[1,2], Z M Razlan[1,2], M K Faizi[1,2], A Harun[1,3], N S Kamarrudin[1,2], I Ibrahim[1,2], M A M Saad[1,2], M F H Rani[1,2], I Zunaidi[4], M Sahari[5], M S Sarip[5] and M Q H A Razali[5]

[1] Motorsports Technology Research Unit (MoTECH), Universiti Malaysia Perlis, Pauh Putra Campus, 02600 Arau, Perlis, Malaysia
[2] School of Mechatronic Engineering, Universiti Malaysia Perlis, Pauh Putra Campus, 02600 Arau, Perlis, Malaysia
[3] School of Microelectronic Engineering, Universiti Malaysia Perlis, Pauh Putra Campus, 02600 Arau, Perlis, Malaysia
[4] Technopreneur at UniMAP Sdn Bhd, No 26, Blok D, Bangunan PPPIT, Pengkalan Jaya, Jalan Kangar - Alor Setar, Taman Mutiara, 01000 Kangar, Perlis, Malaysia
[5] Malaysia Automotive Institute, Block 2280, Jalan Usahawan 2, Cyber 6, 63000 Cyberjaya, Selangor, Malaysia

shahriman@unimap.edu.my

Abstract. Driving cycle is a series of data points representing the speed of vehicle versus time and used to determine the performance of vehicle in general. One of the critical portions of driving cycle development is route selection methodology. This paper describes the efficient methodology of route selection for driving cycle development. Previous data from JKR Road Traffic Volume Malaysia (RTVM) in 2015 is studied and analysed to propose the methodology in route selection. The selected routes are then analysed by using Google Maps. For each region, four (4) routes are selected for each urban and rural. For this paper, the selection of route is focused on northern region of Malaysia specifically in Penang. Penang is chosen for this study because it is one of the developed state in Malaysia that has many urban and rural routes. The methods of route selection constructed in this study could be used by other region to develop their own driving cycles.

1. Introduction

Driving cycle is a series of data points representing the speed of vehicle versus time that are produced by various countries and organizations to determine the performance of vehicles in terms of fuel consumption and carbon emissions [1]. Every driving cycle features the specific route conditions of a particular place and differs widely. Therefore, the driving cycles developed in a certain country or region may not applicable for other regions unless the driving characteristics are evidently similar. Thus, much research work is aimed towards developing driving cycles for a specific country or region [2, 3, 4, 5].

A vehicle driving cycle for a certain region is developed in order to represent the driving pattern that the vehicles would experience repetitively during the journeys when driving in the considered region. Hence, a typical driving cycle for a city must be obtained from traffic data along the travelled routes of those vehicles. The number of such possible route can be huge and it is impractical to

conduct actual assessment of the vehicle speed characteristics on all the routes. An effective way to resolve this problem is to select a number of routes that represent the dominant traffic conditions throughout the region [6]. To do so, an approach is needed to perform a smart selection of routes for the data collection. This paper proposes a comprehensive methodology of route selection in order to determine the most preferable routes for the collection of vehicle speed-time data.

2. Route Selection Methodology

In order to select the routes that can best represent certain traffic condition, the actual situations that happen along each route must be identified and ascertained. Previous data from Malaysian Public Works Department (JKR) Road Traffic Volume Malaysia (RTVM) in 2015 is studied and analysed to propose the methodology in route selection for the northern region of Malaysia specifically in Penang. There are 26 census stations in Penang that have been included in the data collection of traffic flow from JKR in 2015 [7]. The approach is based on the determination of the traffic condition at peak hours and the analysis of the traffic volume. The steps needed to complete this approach are outlined in the following sections.

2.1. Determine ratio of peak hour to 16 hours traffic volume

The first step in the route selection method is to determine the ratio of peak hour to 16 hours traffic volume. As shown in

Table **1**, the data from JKR RTVM in 2015 for Penang region is extracted and the ratio is calculated by dividing the peak hour traffic flow with 16 hours traffic flow for each census station number. The ratio represents the volume of traffic specifically at peak hours compared to the numbers in 16 hours traffic. This method is preferable as the ratio represents real usage of the routes during peak hours. This in essence shows the specific volume rather than throughout the whole 16 hours.

Table 1. Raw data from JKR RTVM in 2015 for Penang region.

Census Station Number	Level of Service (LOS)	Traffic Flow (Peak Hour)	Traffic Flow (16H)	Road Length (KM)	Type of Carriageway	Ratio
PR101	A	992	6,688	12.9	T 1-1	0.148
PR102	B	1,663	18,230	19.0	T 1-1	0.091
PR103	F	3,549	34,613	8.1	T 1-1	0.103
PR104	F	3,121	27,980	12.1	T 1-1	0.112
PR105	A	1,247	10,709	25.4	T 1-1	0.116
PR106	C	1,085	10,955	21.7	T 1-1	0.099
PR107	F	2,426	22,437	8.1	T 1-1	0.108
PR108	F	4,753	44,252	20.9	T 1-1	0.107
PR109	F	5,611	49,173	15.8	T 1-1	0.114
PR110	C	2,948	37,662	9.7	T 2-2	0.078
PR111	A	461	3,924	20.9	T 1-1	0.117
PR112	F	3,712	41,603	3.2	T 2-2	0.089
PR116	F	5,818	65,716	16.9	T 1-1	0.089
PR117	F	11,690	128,962	8.1	K 2-2	0.091
PR113	F	1,872	20,751	24.2	T 1-1	0.090
PR114	F	1,232	13,014	30.6	T 1-1	0.095
PR115	F	3,351	42,147	32.2	T 1-1	0.080
PR201	A	3,007	24,774	11.1	K 2-2	0.121
PR202	F	6,646	67,612	65.5	K 2-2	0.098
PR207	F	3,053	32,022	11.0	T 1-1	0.095
PR208	E	8,868	97,112	0.5	K 3-3	0.091
PR203	B	6,461	62,464	57.2	K 3-3	0.103
PR204	F	2,054	18,614	45.1	T 1-1	0.110
PR205	A	1,046	10,843	38.6	T 1-1	0.096

PR206	C	1,482	12,493	16.9	T 1-1	0.119
PR209	C	6,109	54,699	7.0	K 3-3	0.112

2.2. Ranking up the route based on Level of Service (LOS) followed by ratio of peak hour to 16 hours traffic volume on the specific LOS

Level of Service (LOS) of a traffic facility is an approach introduced to describe the quality of traffic service to a given flow rate. It is introduced by Highway Capacity Manual (HCM) to indicate the level of quality that can be obtain under different operation characteristics and traffic volume. By referring to figure 1, there are six LOS letters defined by HCM included A, B, C, D, E and F. LOS-A denotes the best quality of service whereas LOS-F denote the worst [7].

Figure 1. Description of Level of Services (LOS) [7].

Based on the table 2, the census station number is then ranked according to LOS; starting by LOS-F followed by LOS-E until LOS-A. After that, it is ranked by the highest to the lowest ratio of peak hour to 16 hours traffic volume on the specific LOS. Table 2 shows ranked data based on LOS and the ratio for Penang region.

Table 2. Ranked data based on LOS and ratio for Penang region.

Census Station Number	Level of Service (LOS)	Traffic Flow (Peak Hour)	Traffic Flow (16H)	Road Length (KM)	Type of Carriageway	Ratio
PR109	F	5,611	49,173	15.8	T 1-1	0.114
PR104	F	3,121	27,980	12.1	T 1-1	0.112
PR204	F	2,054	18,614	45.1	T 1-1	0.110
PR107	F	2,426	22,437	8.1	T 1-1	0.108
PR108	F	4,753	44,252	20.9	T 1-1	0.107
PR103	F	3,549	34,613	8.1	T 1-1	0.103
PR202	F	6,646	67,612	65.5	K 2-2	0.098
PR207	F	3,053	32,022	11.0	T 1-1	0.095
PR114	F	1,232	13,014	30.6	T 1-1	0.095
PR117	F	11,690	128,962	8.1	K 2-2	0.091
PR113	F	1,872	20,751	24.2	T 1-1	0.090
PR112	F	3,712	41,603	3.2	T 2-2	0.089

PR116	F	5,818	65,716	16.9	T 1-1	0.089
PR115	F	3,351	42,147	32.2	T 1-1	0.080
PR208	E	8,868	97,112	0.5	K 3-3	0.091
PR206	C	1,482	12,493	16.9	T 1-1	0.119
PR209	C	6,109	54,699	7.0	K 3-3	0.112
PR106	C	1,085	10,955	21.7	T 1-1	0.099
PR110	C	2,948	37,662	9.7	T 2-2	0.078
PR203	B	6,461	62,464	57.2	K 3-3	0.103
PR102	B	1,663	18,230	19.0	T 1-1	0.091
PR101	A	992	6,688	12.9	T 1-1	0.148
PR201	A	3,007	24,774	11.1	K 2-2	0.121
PR111	A	461	3,924	20.9	T 1-1	0.117
PR105	A	1,247	10,709	25.4	T 1-1	0.116
PR205	A	1,046	10,843	38.6	T 1-1	0.096

2.3. Select the urban route based on the ratio of peak hour to 16 hours traffic volume closest to average value

As LOS-F denotes the worst traffic conditions, it is then classified as urban route in Penang region. Four (4) routes were selected based on the closest value to average ratio with consideration of 30-32 samples per route to be examined in the experimental works. From table 3, the average ratio for LOS-F is 0.099. The routes that have the closest ratio to 0.099 are PR103 (0.103), PR202 (0.098), PR207 (0.095) and PR114 (0.095). By examining these four (4) selected routes, the 120 – 128 data samples will be exist which are enough for statistical analysis.

Table 3. Ranked data of LOS-F based on ratio for Penang region.

Census Station Number	Level of Service (LOS)	Traffic Flow (Peak Hour)	Traffic Flow (16H)	Road Length (KM)	Type of Carriageway	Ratio
PR109	F	5611	49173	15.8	T 1-1	0.114
PR104	F	3121	27980	12.1	T 1-1	0.112
PR204	F	2054	18614	45.1	T 1-1	0.110
PR107	F	2426	22437	8.1	T 1-1	0.108
PR108	F	4753	44252	20.9	T 1-1	0.107
PR103	F	3549	34613	8.1	T 1-1	0.103
PR202	F	6646	67612	65.5	K 2-2	0.098
PR207	F	3053	32022	11	T 1-1	0.095
PR114	F	1232	13014	30.6	T 1-1	0.095
PR117	F	11690	128962	8.1	K 2-2	0.091
PR113	F	1872	20751	24.2	T 1-1	0.090
PR112	F	3712	41603	3.2	T 2-2	0.089
PR116	F	5818	65716	16.9	T 1-1	0.089
PR115	F	3351	42147	32.2	T 1-1	0.080
					Average	0.099

2.4. Select the rural route based on the ratio of peak hour to 16 hours traffic volume closest to the average value

Based on JKR justification, LOS-A represent no congestion on a particular traffic condition. Hence, LOS-A could be considered as rural route in Penang region. Four (4) routes were selected with consideration of 30-32 samples per route to be examined in the experimental works. From Table 4, the average ratio for LOS-A is 0.120. The routes that have the closest ratio to 0.120 are PR201 (0.121), PR111 (0.117), PR105 (0.116) and PR205 (0.096). By examining these four (4) selected routes, the 120 – 128 data samples will be exist which are enough for statistical analysis.

Table 4. Ranked data of LOS-A based on ratio for Penang region.

Census Station Number	Level of Service (LOS)	Traffic Flow (Peak Hour)	Traffic Flow (16H)	Road Length (KM)	Type of Carriageway	Ratio
PR101	A	992	6688	12.9	T 1-1	0.148
PR201	A	3007	24774	11.1	K 2-2	0.121
PR111	A	461	3924	20.9	T 1-1	0.117
PR105	A	1247	10709	25.4	T 1-1	0.116
PR205	A	1046	10843	38.6	T 1-1	0.096
					Average	0.120

3. Result and Discussion

A comprehensive route selection methodology for Penang region has been deliberate in the previous section. There are four (4) routes each for urban and rural road have been selected. For this section, each route will be discuss thoroughly including description of location and also self-assessment of the route geography and exact location using Google Maps.

3.1. Selected urban and rural route

Based on Table 3, the average ratio of peak hour to 16 hours traffic volume for LOS-F is 0.099. Four (4) census station number which has the ratio closest to the average value are PR103, PR202, PR207 and PR114. Table 5 shows the description of location for selected urban route.

Table 5. Selected urban route.

Census Station Number	Description of Location
PR103	Butterworth – Bagan Ajam – Telok Ayer Tawar
PR202	George Town – Bayan Lepas – Gelugor (Jalan Keliling Pulau)
PR207	Paya Terubong – Ayer Hitam
PR114	Butterworth – Tasek – Val D'or

Based on table 4, the average value of ratio of peak hour to 16 hours traffic volume for LOS-A is 0.120. Four (4) census station number which has the ratio closest to the average value are PR201, PR111, PR105 and PR205. Table 6 shows the description of location for selected rural route.

Table 6. Selected rural route.

Census Station Number	Description of Location
PR201	George Town – Telok Bahang (Jalan Keliling Pulau)
PR111	Butterworth – Bukit Mertajam – Junjong (Through Machang Bubok – Tasek)
PR105	100m from Ara Kuda – Lunas Junction
PR205	George Town – Telok Bahang – Balik Pulau (Jalan Keliling Pulau)

3.2. Self-assessment of the route geography and exact location using Google Maps

Based on the previous section, the urban route that selected are PR103, PR202, PR207 and PR114. On the other hand, the rural routes that were selected are PR201, PR111, PR105 and PR205. Figure 2 shows the location of selected urban and rural route in Penang. Blue circles denote selected urban route whereas green circles denote selected rural route. From the figure, we can see that these routes were not in same networks or chains. Hence, these routes are acceptable to be selected to represent urban and rural routes in Penang region.

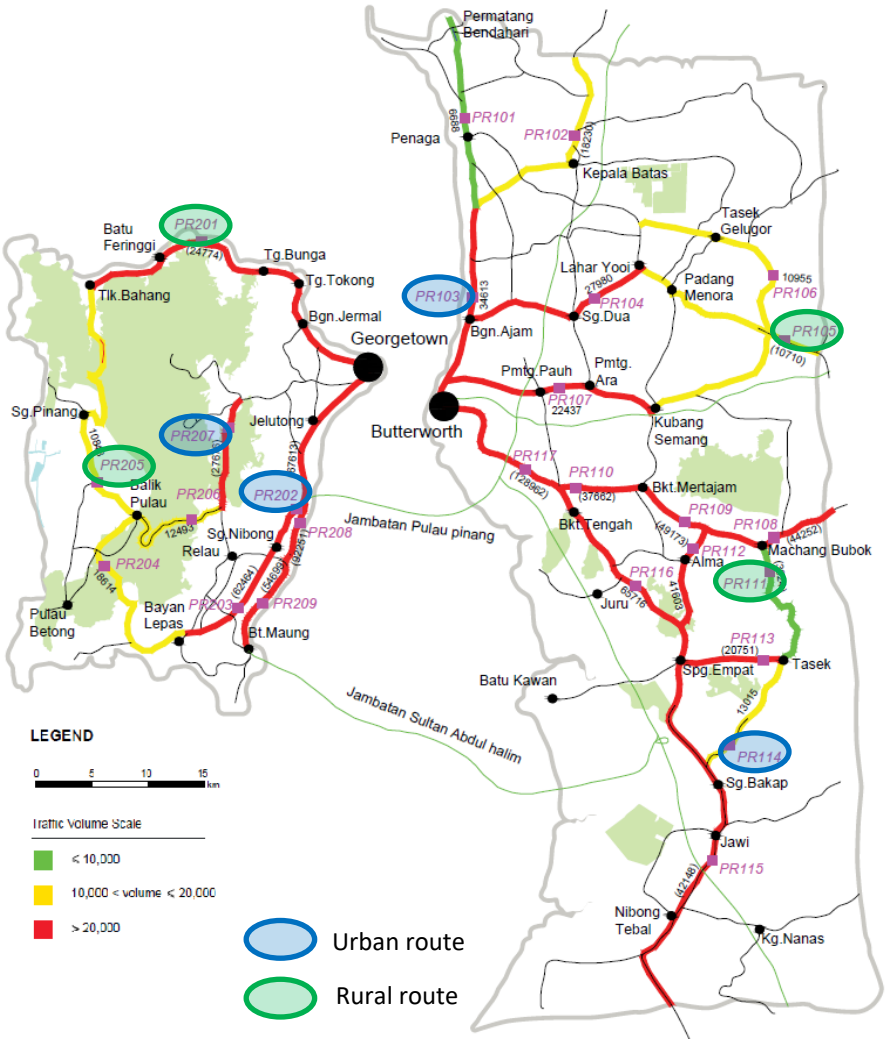

Figure 2. Location of selected urban and rural route in Penang.

Figure 3 to figure 10 show the exact location of each selected routes using Google Maps. The screenshot is taken at peak hour for each location. There are 4 colour intensities that has been introduced by Google Maps to show the congestion level of the certain routes. Green colour denotes fast traffic flow, yellow colour denotes slower traffic movement followed by red.

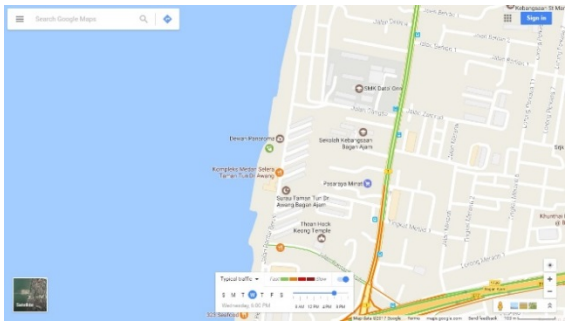

Figure 3. PR103 (Butterworth – Bagan Ajam – Telok Ayer Tawar)

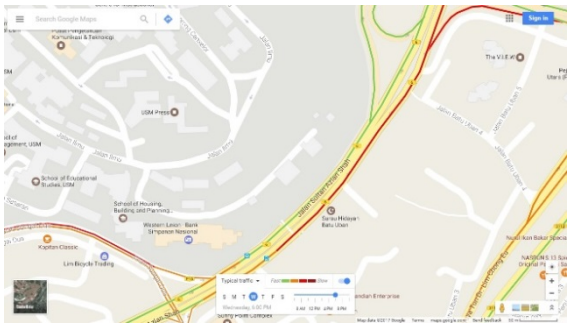

Figure 4. PR202 (George Town – Bayan Lepas – Gelugor (Jalan Keliling Pulau)

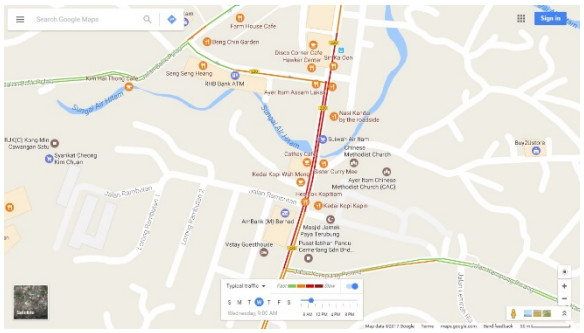

Figure 5. PR207 (Paya Terubong – Ayer Hitam)

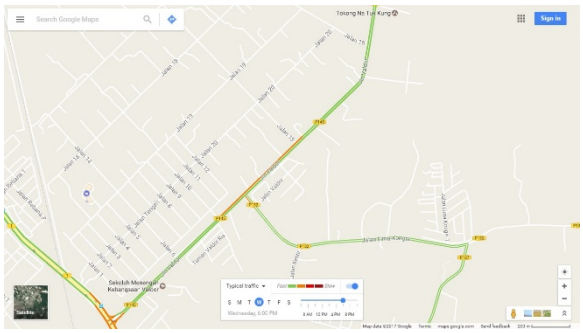

Figure 6. PR114 (Butterworth – Tasek – Val D'or)

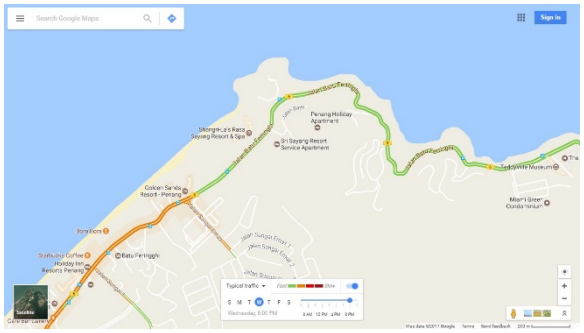

Figure 7. PR201 (George Town – Telok Bahang (Jalan Keliling Pulau)

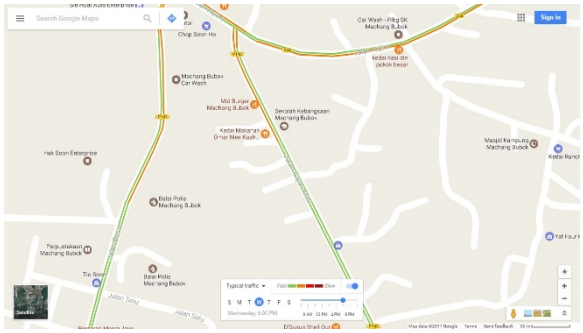

Figure 8. PR111 (Butterworth – Bukit Mertajam – Junjong (Through Machang Bubok – Tasek)

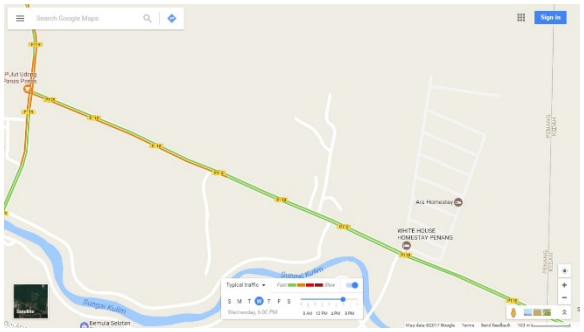

Figure 9. PR105 (100m from Ara Kuda – Lunas Junction)

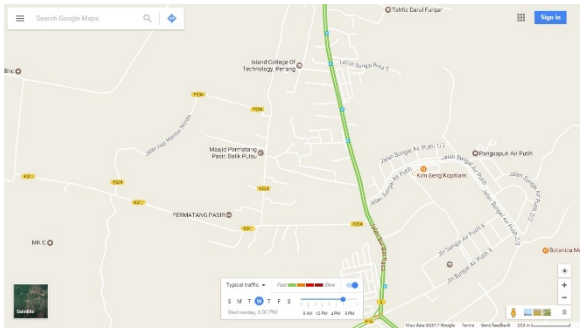

Figure 10. PR205 (George Town – Telok Bahang – Balik Pulau (Jalan Keliling Pulau)

3.3. Routes in the same network and chain

The route that has the same networks or chains must be avoided. If any, the other route that closest to the average value of ratio should be selected. Figure 11 shows the example of routes that located in the same network and chain. PR207 and PR206 are in the same network and chain, although different congestion level (differentiate by colour). Moreover, PR208 and PR209 are also in the same network and chain and in the same congestion level. These kind of routes could not be selected both. It just can be select only one of them.

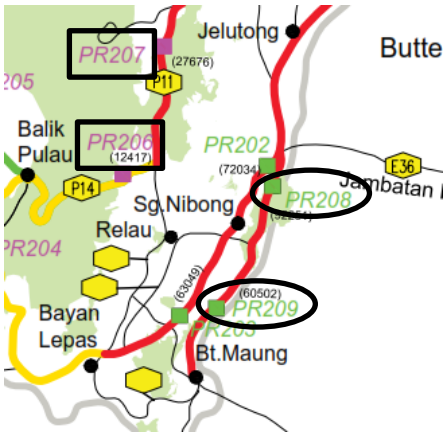

Figure 11. Example of routes in the same network and chain.

4. Conclusion

A methodology of route selection has been thoroughly described in this study. By referring to the data from JKR RTVM in 2015 specifically in Penang, the method by using ratio of peak hour to 16 hours traffic volume is developed. Based on the approach, this method is a preferable method as the ratio represents real usage of the routes during peak hours and ranking the ratio would rank the road in congestion level order. Besides, the average ratio is obtained to represents the data in normally distributed approach. The method of route selection that has been constructed in this study is very effective and could be used to determine routes to be chosen at other region for driving cycle's development.

5. Acknowledgments

The author acknowledge the financial support from Malaysia Automotive Institute (MAI) under research grant of Malaysia Driving Cycle.

6. References

[1] Brundell-Freij K and Ericsson E 2005 Influence of street characteristics, driver category and car performance on urban driving patterns *Transp. Res. Part D Transp. Environ.*, vol. 10, no. 3, pp. 213–229

[2] Lin J and Niemeier D A 2003Regional driving characteristics, regional driving cycles," *Transp. Res. Part D Transp. Environ.* **vol. 8** no. 5, pp. 361–81

[3] Hung W. T., Tong H Y, Lee C P, Ha K, and Pao L Y 2007 Development of a practical driving cycle construction methodology: A case study in Hong Kong," *Transp. Res. Part D Transp. Environ.*, **vol. 12** no. 2, pp. 115–28

[4] Kamble S H, Mathew T V, and Sharma G K 2009 Development of real-world driving cycle: Case study of Pune, India," *Transp. Res. Part D Transp. Environ.*, **vol. 14** no. 2, pp. 132–40

[5] T. Nutramon and C. Supachart 2009 Influence of driving cycles on exhaust emissions and fuel consumption of gasoline passenger car in Bangkok *J. Environ. Sci.*, **vol. 21** no. 5, pp. 604–11

[6] Tamsanya S, Chungpaibulpatana S, and Limmeechokchai B 2009 Development of a driving cycle for the measurement of fuel consumption and exhaust emissions of automobiles in Bangkok during peak periods *Int. J. Automot. Technol.*, **vol. 10** no. 2, pp. 251–64

[7] Highway Planning Unit 2016 *Road Traffic Volume Malaysia 2015* Ministry of Works Malaysia, Highway Planning Division p. 262.