Efficient methodology of route selection for driving cycle development

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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 conditions, 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.

| 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 |
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].](image)

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.

| Census Station Number | Level of Service (LOS) | Traffic Flow (Peak Hour) | Traffic Flow (16H) | Road Length (KM) | Type of Carriageway | Ratio |
|-----------------------|------------------------|--------------------------|--------------------|------------------|---------------------|-------|
| 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 |

| 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 |
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 | 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)
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.
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.

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6. References
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