Batu Pahat Driving Cycle for Light Duty Gasoline Engine

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Abstract. Driving cycle is a series of data points that represents the vehicle speed versus time. Transient driving cycles involve many changes such as frequent speed changes during typical on-road driving condition [2]. Model driving cycles involve protracted periods at constant speeds. The Batu Pahat Driving Cycle (BPDC) developed to represent the driving pattern of people in a district of Batu Pahat. Based on this driving cycle, it will be a reference to other researchers to study about the gases emission release and fuel consumption by the vehicle on the dynamometer or automotive simulation based on this driving cycle. Existing driving cycles used such as the New European Driving Cycle (NEDC), the Federal Test Procedure (FTP-72/75, and Japan 10-15 Mode Cycle is not appropriate for Batu Pahat district because of different road conditions, driving habits and environmental of developed driving cycle countries are not same [2][14]. Batu Pahat drive cycle was developed for low-capacity gasoline engine under 150 cc and operating on urban roads, rural roads and road around Universiti Tun Hussein Onn. The importance of these driving cycle as the reference for other research to measure and do automotive simulation regarding fuel consumption and gas emission release from the motorcycle for these three type of driving cycle area. Another use for driving cycles is in vehicle simulations [3]. More specifically, they are used in propulsion system simulations to predict the performance of internal combustion engines, transmissions, electric drive systems, batteries, fuel cell systems, and similar components [18]. Data collection methods used in this study is the use of Global Positioning System (GPS). The results obtained are not similar to each other due to differences in congestion on data taken. From the driving cycle graph obtained, such as the average velocity, maximum velocity, the duration and Positive Acceleration Kinetic Energy (PKE) can be determined. In addition, the best driving cycle sample can be determined from the sum of error calculated. The least sum of error means the best driving cycle

1. Introduction

Exhaust gas emissions cause more serious problems to the environment. The gasoline engine produces gas emissions such as carbon monoxide (CO), hydrocarbons (HC) and nitrogen oxides (NOx). These gasses are harmful to the environment because of toxic and causes air pollution, greenhouse effect and disease [3]. The internal combustion engine that releases the emission is divided into two modes, “on-road” and “off-road” based on their sources. On road vehicles include motorcycles, cars, buses, truck, and so on while the “off-road” such as generator engine, aircraft, ships and so on [4]. The “on-road”
vehicle is the largest contributor of emission to the environment [6]. In the year 2000, the “on-road”
vehicle has accounted for 44% of carbon monoxide (CO), 33% of nitrogen oxide emissions (NOx) and
one percent other particles [1].

These emissions are byproducts from the engine combustion process and from the evaporation of
fuel. Despite the ever-growing number of vehicles on the road, studies show that ten to thirty percent
of vehicles cause the majority of vehicle-related air pollution [15]. Due to this, the community has
taken this problem seriously and research has been conducted to measure the exhaust gas emissions
and saves fuel consumption [14]. Therefore, many countries have developed a system called driving
cycle which is to measure the driving pattern of the research area. From the driving cycle developed,
the other researcher will continue the research as to measure the gas emission and fuel consumption of
the tested vehicle on the chassis dynamometer based on the driving cycle developed. However, the
driving cycle was developed according to the certain characteristics and circumstances. For a country
that has developed a drive cycle, it was by the standards of that country only and not intended for use
in other countries [7]. Driving cycle used to evaluate vehicle performance in many ways, the most
common example is to assess pollution and fuel consumption in the vehicle certification program
[13][16]. Most systems using the concept of macroscopic emissions driving cycle for the collection of
valuable data, on the other hand, microscopic emission model using the driving cycle to immediately
switch production to average emission factors [1].

Based on this situation, the driving cycle for Batu Pahat districts was developed as to study the
driving pattern base on this road and traffic condition. Batu Pahat Driving Cycle was developed based
on driving, road and traffic conditions, especially for motorcycle rider that riding with a different
characteristic compared other countries. The study was conducted in two different road conditions
during peak hour which is on urban roads and rural roads. For urban road condition, there are many
corners thus the traffic will slow-moving and many stops. While for rural road condition, the road was
long, fewer corners and vehicles stop rarely compared to urban condition.

2. Methodology
The most common method used to conduct this research is to select a combination of the finest micro
journey to represent the velocity (v) data per unit time (t). The micro trip is defined as part of the data
in the idle mode border (zero speed) at both ends. Most of the existing drive cycle was developed
using micro journey. To carry out this research, the important factors that must be consider was
driving style or driving behavior is usually done by the public every day. This means all the variables
that affect this study such as a driver, vehicle and traffic conditions should be considered in order to
get a good data. The common methods used to represent the drive cycle is to use the experimental
methods such as the use of the vehicles on the road test and the data obtained will record. The rider
used to ride the motorcycle for all three different modes of driving cycle must be the same rider as to
avoid another factor that affects the result. The different rider had different weight thus it will affect
the speed of the vehicle as the load increase or decrease. Same goes to the motorcycle use to complete
all the data obtain, the same motorcycle also must be used as there is no modified on the engine. The
effect on the type of gasoline (RON) also must be considered which can affect the engine
performance. The gasoline used to drive the engine was RON 95 from Petron station.

2.1 Road Selection
The selection of routes was the first method done when to conduct this driving cycle study. The
selection should be made according to the circumstances or priorities through the road [2]. In this
study, the selected route is around Batu Pahat town, which is a reference for the urban area, while the
route for the rural areas was around Parit Raja. For the Batu Pahat driving cycle for both areas which
are urban and rural, the road condition such as traffic condition, time and weather must be considered
as to increase the quality of data obtained [7][8]. While running the experiment, all the 3 factor stated
must be considered and running at the same condition. This work adopted the motorcycle-to-motorcy-
A follow-up method was used to establish on-road driving cycles with an instrumented motorcycle. The starting point on a road was selected first; the surveyors then randomly selected a passing driver (target) and followed this target to their destination. To avoid short driving patterns, successful follow-ups were required to have a duration of at least 600s (or 11 min) and up to 700s. Cycle with a duration of well below 600s were abandoned and the surveyors returned to the starting point to begin a new cycle. When the target driver drove aggressively (not normally or conservatively), the cycle was also abandoned for safety reasons. It was found that the fraction of driving trips abandoned due to aggressive driving was below 8% in the rural regions and below 5% in the urban regions [3]. After each successful cycle, which represented a driving trip, the surveyors returned to the origin and selected another target for a new cycle. Five successful driving trips were obtained for every starting site in the urban areas, rural and UTHM. For the urban area, total 7km travel distance had been done while for rural area the total travel distance was 5.4km.

![Routing represented the urban areas by using Google Maps.](image)

In addition, this study was also done to the route of University Tun Hussein Onn Malaysia (UTHM). The selected route started from a T-junction near F2 to the Library building Tunku Tun Aminah. These three type of routing was selected due to several factors that consider such as a number of population for a rural and urban area and traffic condition [7]. For UTHMDC routing, the selected route had been choosing due to road condition and traffic that can be controlled by choosing the suitable time to run the research. The weather while running the research also must be considered as to avoid the error of data taken. All the data were taken when the weather was clear (not raining).
Therefore, this study was also conducted for the route in the vicinity of Universiti Tun Hussein Onn Malaysia (UTHM). The selected route starting from the intersection of T-junction near the building F2 to the Tunku Tun Aminah Library. The total distance travel was 2.2 km. The journey starts from the intersection of T and the Faculty of Computer Science and Information Technology (FSKTM), then through the Faculty of Electrical and Electronic Engineering (UMP), as well as through the Faculty of Civil and Environmental Engineering (FKAAS). The journey continues through the Faculty of Technical and Vocational Education (FPTV), Faculty of Business Technology Management and Entrepreneurship (FPTP), Library Tunku Tun Aminah and so on back to the start of the journey.

2.2 Data collection method
In developing driving cycles for Batu Pahat district, the most suitable method to measure the data is by using the Global Positioning System (GPS) [8]. Global Positioning System (GPS) which is easy to use as well as low cost and friendly user. The scope of this study was to use the small capacity gasoline engine of motorcycles under 150 cc. This motorcycle engine specification was overhead cam (OHC) 2-valve, four-stroke engine with a capacity of 97.1 cc. Horsepower for this tested motorcycle was 8.9 hp at 8000 rpm and torque 0.93 kgf/m at 6000 rpm.
2.3 Global Positioning System (GPS)
In developing the drive cycle, there are various ways to get the data. The methods used to collect data is the car chase. This method is done by installing control devices distance between vehicles and choose targets at random by the laser beam. Cycle drive using this method is Edinburgh Motorcycle Driving Cycle (EMDC) [4]. In addition, modern methods were used to obtain data with the Global Positioning System (GPS) which is used in addition to a low cost of operation [15]. The drive cycle that using this method is Dhaka City Driving Cycle (Bangladesh) [7], and Brasov City Driving Cycle (Romania) [5]. In developing the standard drive cycle for Batu Pahat, the most suitable method used is the GPS.

GPS devices began to be used for measuring travel data method since the late 1990s [11]. The early device used only in the vehicle and the derive power from the accessory socket of the car. In the 2000s, the first wearable produces using the batteries power from rechargeable batteries. The weakness of the device was too heavy and ungainly, and the people less to use the devices [11].

![Figure 4. Early wearable GPS device shown by a mobile telephone [11].](image)

2.4 Small capacity motorcycle
The scope of this study is set to low-powered motorcycle that is under 150 cc. Motorcycles are often used in Malaysia which has a lower capacity of under 150 cc engine such as Honda EX5 which 100 cc, Honda Wave which 125 cc, 110 cc of Yamaha Legenda, Yamaha 135 LC, and so on. In this study, the selected motorcycles were 100 cc Honda EX5, as shown in Figure 5. This motorcycle engines overhead cam (OHC) 2-valve, four-stroke engine with a capacity of 97.1 cc. Horsepower of this bike is 8.9 PS at 8000 rpm and a torque of 0.93 kgf.m at 6000 rpm [12]. This motorcycle has a maximum speed of 95 km/hour. The selected factor using this type motorcycle because of the specification and number used in this study area. This motorcycle specification meets the requirement specification of the study scope. Bases on statistic data from Department of transport and road safety portal, it state that the number of motorcycle users is larger than other transport vehicle. Due to this statement, it became one of the selected factor of vehicle in doing this study.
2.5 Selection of Assessment Measures
A method for determining the driving cycle will be done by collecting five samples and analysed data graphs. The estimated error for each graph variables such as velocity, acceleration, deceleration, and acceleration energy per mile (Positive Acceleration Kinetic Energy, PKE) [9] will be determined. The sum of the error for each of the lowest will be chosen as driving cycle [10][17][18].

2.6 Development of driving cycles
In this method, a set of micro-trips are randomly and repeatedly selected from generated micro-trips to combine a large number of candidate driving cycles first. Then, the final driving cycle is selected based on the selected assessment measures. The candidate driving cycle with the least values of assessment measures is usually selected as the final cycle since it can approximately replicate the trend and characteristics of the collected whole driving dataset [10][14].

2.7 Parameter and formula
As to complete all the data obtain, there are several formulas used to calculate the data such as average velocity, average acceleration, average deceleration, potential kinetic energy (PKE) and error. All the formula use had listed below.

\[
\text{Average velocity} = \frac{\sum v}{T} \quad (1)
\]

\[
\text{Average acceleration} = \frac{\sum (V^2 - V_1^2)}{T} \quad (+v) \quad (2)
\]

\[
\text{Average deceleration} = \frac{\sum (V^2 - V_1^2)}{T} \quad (-v) \quad (3)
\]

\[
\text{PKE} = \sum (\frac{v^2}{2} - \frac{v_1^2}{2}) \quad (+v) \quad (4)
\]

\[
\text{Error, } e = \left\{ \frac{p_i - P'}{p_i} \right\} \times 100 \quad (5)
\]

Where T is equal to total time taken, t is time taken, V1 is initial velocity, V2 is final velocity, P' is average of variable and Pi is average idle time.

Table 1 below lists the 13 parameters used to characterize a driving cycle and their associated meanings. Note that most of these parameters were also used to characterize the driving cycles of four-wheel automobiles [19]. The values of individual cycle parameters can be directly derived from the
instantaneous speed–time data for driving trips, after which the sample means for individual parameters in individual trips can be determined. L is a total distance traveled in a cycle, V is an average speed in a cycle including idle periods, \( V_{\text{max}} \) is a maximum speed in a cycle excluding idle periods, A is a rate of change of speed above 0.1 m/s\(^2\) using average values, and the last was D is a rate of change of speed below -0.1 m/s\(^2\) using average values.

Table 1. Parameters used to characterize driving cycles in this study

| No. | Driving Cycle Variable          | Symbol/unit   |
|-----|---------------------------------|---------------|
| 1   | Average velocity               | V (km/jam)    |
| 2   | Maximum velocity               | \( V_{\text{max}} \) (km/jam) |
| 3   | Average acceleration           | A (m/s\(^2\)) |
| 4   | Average deceleration           | D (m/s\(^2\)) |
| 5   | Maximum acceleration           | \( A_{\text{max}} \) (m/s\(^2\)) |
| 6   | Maximum deceleration           | \( D_{\text{max}} \) (m/s\(^2\)) |
| 7   | Potential kinetic energy       | PKE           |
| 8   | Sum of error                   | E             |
| 9   | Error                          | e             |
| 10  | Average of variable            | \( P' \)      |
| 11  | Percentage of idling time      | \( P_i \) (%) |
| 12  | Travel distance                | L (km)        |
| 13  | Rate                           | I (s)         |

3. **Result and discussion**

This chapter describes and analyses the results obtained from the study that has been done. The results are from study data on city streets and rural roads and also along UTHM route. Some sets of data have been taken to obtain better results. The sample data were taken with the uniform during peak hours between 4 to 6 pm. Five sets of sample graphs taken while only one sample graph having the lowest error is selected as a reference.

Referring to Table 2(a) and 2(b) below, five sets of sample data were taken which are to measure the average velocity, maximum velocity and so on as stated in the table. For the average velocity and maximum velocity, the highest score was from sample 1 which is 40.5km/h and 70km/h. Data from sample 5 show the highest value for average acceleration which is 0.48m/s\(^2\) and for the value of average deceleration, sample 2 show the highest deceleration result which is -0.62m/s\(^2\). In addition, the highest score for maximum acceleration and the minimum score for maximum deceleration was score by sample 3 which is 1.39m/s\(^2\) and sample 4 was -0.06m/s\(^2\). For PKE data, sample 5 show the highest value which is 0.92m/s\(^2\) and for the idling time, sample 3 shows the highest score which is 15.30s.

Table 2(a). Parameter for each sample for urban driving cycle.

| Sample | Average velocity (km/h) | Maximum velocity (km/h) | Average acceleration (m/s\(^2\)) | Average deceleration (m/s\(^2\)) |
|--------|-------------------------|-------------------------|----------------------------------|----------------------------------|
| 1      | 40.5                    | 70                      | 0.38                             | -0.49                            |
| 2      | 38.9                    | 60                      | 0.44                             | -0.62                            |
| 3      | 33.1                    | 60                      | 0.45                             | -0.48                            |
| 4      | 34.6                    | 60                      | 0.45                             | -0.49                            |
| 5      | 39.7                    | 60                      | 0.48                             | 0.57                             |

Table 2(b). Parameter for each sample for urban driving cycle
Table 3(a) and 3(b) shows the data for approximate sum of error of each sample for the urban driving cycle. For the lowest value of approximate error for average velocity, maximum velocity and average acceleration were scored by sample 2 which is -53.8km/h, -137.4km/h and 93.7m/s\(^2\). Sample 1 shows the lowest approximate error for average acceleration and deceleration which are 95.0m/s\(^2\) and 87.3m/s\(^2\). Besides that, sample 4 give the lowest value for maximum deceleration which is 100.4m/s\(^2\) while sample 2 give the lowest approximate error for PKE which is 89.

**Table 3(a).** Approximate sum of error of each sample for urban driving cycle.

| Sample | Average velocity (km/h) | Maximum velocity (km/h) | Average acceleration (m/s\(^2\)) | Average deceleration (m/s\(^2\)) |
|--------|-------------------------|-------------------------|----------------------------------|----------------------------------|
| 1      | -14.3                   | -82.9                   | 96.1                             | 95.0                             |
| 2      | **-53.8**               | **-137.4**              | **93.7**                         | **108.8**                        |
| 3      | 39.7                    | -8.95                   | 97.1                             | 103.1                            |
| 4      | 34.6                    | -13.4                   | 96.9                             | 103.3                            |
| 5      | -19.1                   | -80.0                   | 94.8                             | 106.2                            |

**Table 3(b).** Approximate sum of error of each sample for urban driving cycle.

| Sample | Maximum acceleration (m/s\(^2\)) | Maximum deceleration (m/s\(^2\)) | PKE (m/s\(^2\)) | Sum of error |
|--------|----------------------------------|----------------------------------|-----------------|--------------|
| 1      | 87.3                             | 101.4                            | 92.1            | 374.7        |
| 2      | **88.2**                         | **103.9**                        | **89.7**        | **293.1**    |
| 3      | 90.9                             | 101.8                            | 95.3            | 518.9        |
| 4      | 92.4                             | 100.4                            | 94.0            | 508.2        |
| 5      | 88.0                             | 103.0                            | 90.1            | 383.0        |

The lowest sum of error estimate is taken as the reference for choosing the driving cycle pattern. Referring to Table 2 above, the data from sample 2 was taken as the Batu Pahat Driving Cycle for an urban area (BPDCu).

Referring to graph velocity(km/h) against time(s) in Figure 6 below, the highest velocity shows at 60km/h. Batu Pahat Driving Cycle for urban (BPDCu), characteristics have the duration of 570 seconds, a distance is 7.0 km, an average velocity is 38.9 km/h and maximum velocity is 60 km/h. Moreover, this cycle has average acceleration of 0.44 m/s\(^2\), and deceleration of - 0.62 m/s\(^2\). The Positive Acceleration Kinetic Energy (PKE) for this cycle is 0.72 m/s\(^2\). BPDCu is a transient cycle. Referring to Figure 6, at the beginning of the cycle where the proportion of 0-100 seconds, the velocity of the vehicle is smooth. At the 100 and 200, the vehicle slowed down due to traffic congestion. At 400 to 570 seconds, the vehicle velocity is smooth until to finish point. As the selected driving cycle from all sample, the graph pattern from sample 2 was chosen as the driving cycle for Batu Pahat urban area.
Based on Table 4(a) and 4(b) below, all the data obtain for each sample for Batu Pahat rural driving cycle (BPDCr). A total of 5 sample of data was taken same goes to the urban area as stated earlier. For the highest average velocity, sample 3 score the highest value which is 53.4km/h where sample 5 give the lowest value for maximum velocity which is 60km/h. Besides that, the highest score for average acceleration and deceleration was scored by data from sample 1 which obtain 0.47m/s² and -0.52m/s². Moreover, data from sample 1 also show the maximum score for maximum acceleration and deceleration which are 1.89m/s² and -0.06m/s². Other than that, the highest score for PKE value was from sample 3 which is 0.87m/ss contrasted to data from sample 5 give the lowest scores about 0.51m/ss. Last but not least, sample 1 score the highest value for the idle time which is 12.8s compared to data from sample 3 show the less value about 5.26s.

**Table 4(a).** Parameter for each sample for rural driving cycle.

| Sample | Average velocity (km/h) | Maximum velocity (km/h) | Average acceleration (m/s²) | Average deceleration (m/s²) |
|--------|------------------------|-------------------------|----------------------------|-----------------------------|
| 1      | 46.9                   | 70                      | 0.47                       | -0.52                       |
| 2      | 47.3                   | 65                      | 0.36                       | -0.49                       |
| 3      | 53.4                   | 70                      | 0.44                       | -0.36                       |
| 4      | 49.1                   | 65                      | 0.45                       | -0.56                       |
| 5      | 49.6                   | 60                      | 0.45                       | -0.50                       |

**Table 4(b).** Parameter for each sample for rural driving cycle.

| Sample | Maximum acceleration (m/s²) | Maximum deceleration (m/s²) | PKE (m/ss) | Idle time (s) |
|--------|-----------------------------|-----------------------------|------------|---------------|
| 1      | 1.89                        | -0.06                       | 0.84       | 12.8          |
| 2      | 1.39                        | -0.14                       | 0.84       | 7.69          |
| 3      | 1.53                        | -0.11                       | 0.87       | 5.26          |
| 4      | 1.39                        | 0.14                        | 0.59       | 7.90          |
| 5      | 1.39                        | -0.14                       | 0.51       | 5.56          |

All the data for approximate error for each sample was calculated and tabulated in Table 5(a) and 5(b) below. Sample 3 give the lowest score for approximate error of average velocity, maximum velocity and average acceleration which are -181.4km/h, -268.8km/h and 91.6m/s². Besides that, the average deceleration and maximum deceleration data from sample 1 give the lowest error which is 104.1m/s².
and 100.5m/s² whereas sample 5 score the lowest error for maximum acceleration which is 75.0m/s². Last but not least, sample 3 score the lowest approximate error for PKE and sum of error for all parameter which are 83.4m/s² and 5.26 compared to data from sample 1 give the highest score which is 93.4m/s² and 426.21 for the sum of error.

The lowest error estimate is taken as the reference for selected driving cycle. Referring to Table 4, sample 3 was taken as the Batu Pahat Driving Cycle (rural). Batu Pahat Driving Cycle (rural) (BPDCr), characteristics consist of 380 seconds of duration, a distance is 5.4 km, an average velocity is 53.4 km/h, and maximum velocity of 70 km/h. Moreover, this average acceleration is 0.44 m/s², and deceleration of – 0.36 m/s². While the PKE for this cycle is 0.87 m/s². Based on Figure 7, at the beginning of the cycle, the velocity of the vehicle has smooth and began to decrease at the 80th seconds. During the 100 to 380 seconds, the velocity of the vehicle is smooth until the end of the cycle.

| Sample | Average velocity (km/h) | Maximum velocity (km/h) | Average acceleration (m/s²) | Average deceleration (m/s²) |
|--------|-------------------------|-------------------------|----------------------------|----------------------------|
| 1      | -1.72                   | -51.6                   | 96.3                       | 104.1                      |
| 2      | -70.87                  | -153.4                  | 95.3                       | 106.3                      |
| 3      | **-181.4**              | **-268.8**              | **91.6**                   | **106.8**                  |
| 4      | -72.2                   | -129.1                  | 94.3                       | 107.1                      |
| 5      | -148.2                  | -200.4                  | 91.9                       | 108.9                      |

| Sample | Maximum acceleration (m/s²) | Maximum deceleration (m/s²) | PKE (m/s²) | Sum of error |
|--------|-----------------------------|-----------------------------|------------|--------------|
| 1      | 85.2                        | 100.5                       | 93.4       | 426.21       |
| 2      | 81.9                        | 101.8                       | 89.1       | 268.2        |
| 3      | **79.9**                    | **102.7**                   | **83.4**   | **5.26**     |
| 4      | 82.4                        | 101.8                       | 92.5       | 276.8        |
| 5      | 75.0                        | 102.5                       | 90.8       | 102.5        |

The lowest error estimate is taken as the reference for selected driving cycle. Referring to Table 4, sample 3 was taken as the Batu Pahat Driving Cycle (rural). Batu Pahat Driving Cycle (rural) (BPDCr), characteristics consist of 380 seconds of duration, a distance is 5.4 km, an average velocity is 53.4 km/h, and maximum velocity of 70 km/h. Moreover, this average acceleration is 0.44 m/s², and deceleration of – 0.36 m/s². While the PKE for this cycle is 0.87 m/s². Based on Figure 7, at the beginning of the cycle, the velocity of the vehicle has smooth and began to decrease at the 80th seconds. During the 100 to 380 seconds, the velocity of the vehicle is smooth until the end of the cycle.

Figure 7. Graph for Batu Pahat Driving Cycle (rural).
Referring to Table 6(a) and 6(b) below, five sets of sample data were taken to measure the average velocity, maximum velocity and so on as stated in the table. For the average velocity and maximum velocity, the lowest score was from sample 5 which is 44.6km/h and 56km/h. Data from sample 4 show the highest value for average acceleration which is 0.42m/s² and for the value of average deceleration sample 1 shows the highest deceleration result which is -0.65m/s². In addition, the highest score for maximum acceleration and the minimum score for maximum deceleration was score by sample 4 which is 1.11m/s² and sample 5 was -0.06m/s². For PKE data, sample 3 show the highest value which is 0.82m/s² compared to data from sample 4 give the lowest score which is 0.62m/s².

| Sample | Average velocity (km/h) | Maximum velocity (km/h) | Average acceleration (m/s²) | Average deceleration (m/s²) |
|--------|-------------------------|-------------------------|-----------------------------|-----------------------------|
| 1      | 47.3                    | 60                      | 0.37                        | -0.65                       |
| 2      | 48.6                    | 60                      | 0.37                        | -0.56                       |
| 3      | 48.8                    | 60                      | 0.31                        | -0.50                       |
| 4      | 50.8                    | 60                      | 0.42                        | -0.52                       |
| 5      | 44.6                    | 56                      | 0.22                        | -0.37                       |

Table 6(b). Parameter for each sample for route of UTHM campus driving cycle.

| Sample | Maximum acceleration (m/s²) | Maximum deceleration (m/s²) | PKE (m/s²) |
|--------|-----------------------------|-----------------------------|------------|
| 1      | 0.83                        | -0.28                       | 0.71       |
| 2      | 0.83                        | -0.28                       | 0.71       |
| 3      | 0.97                        | -0.14                       | 0.82       |
| 4      | 1.11                        | -0.14                       | 0.62       |
| 5      | 0.44                        | -0.06                       | 0.66       |

From the figure 8 above, it shows that the graph pattern was uniformly distributed. The graph was plotted based on data from sample 5. The data sample 5 was selected as the UTHM Driving Cycle (UTHMDC). UTHM Driving Cycle characteristics have a duration of 210 seconds, a distance is 2.2 km, an average velocity is 44.6 km/h, and maximum velocity is 56 km/hour. While this cycle had an average acceleration of 0.22 m/s², and deceleration of – 0.37 m/s². In addition, the PKE for this cycle is 0.66 m/s². Based on Figure 8, at the beginning of the cycle, the velocity of the vehicle smoothly until the end of the cycle.

![Graph showing velocity over time](image)
3.1 Comparison data between BPDC with other existed driving cycle.

Referring to table 7 below, it shows the comparison between BPDC with other 4 existing driving cycle which are Federal Test Procedure (FTP-75), Urban Driving Cycle (ECE-15), Extra Urban Driving Cycle (EUDC) and Japan 10-15 Mode Cycle. All the driving cycle data are used to simulate the condition whereas to determine the emission release and fuel consume by the vehicle. Based on this driving cycle data, all the simulation can be done inside the laboratory and on the dynamometer. EUDC show the highest value of velocity and maximum velocity can be achieve compared to other driving cycle. It is due to the road condition and distance while conducting the experiment.

Different road condition gives the different value of data. UTHMDC shows the lowest score of acceleration and deceleration due to traffic and weather condition. Inside campus, there are many junctions and road user that can affect the acceleration of the vehicle. PKE data shows that BPDCu score the highest value compare to other. The highest PKE value. The highest of fuel consume and gas release to drive the vehicle [15][18].

| Item               | BPDCu | BPDCr | UTHM DC | FTP-75 | ECE 15 | EUDC   | MODE 10-15 |
|--------------------|-------|-------|---------|--------|--------|--------|------------|
| Distance (km)      | 7     | 5.4   | 2.2     | 17.77  | 4x1.013 | 6.955  | 4.16       |
| Idling (s)         | 570   | 380   | 210     | 1874   | 4x195  | 400    | 660        |
| Velocity (km/jam)  | 38.9  | 53.4  | 44.6    | 34.14  | 18.7   | 62.6   | 22.7       |
| Velocitymax (km/jam) | 60   | 70    | 56      | 91.25  | 50     | 120    | 70         |
| Acceleration (m/s²) | 0.44 | 0.44  | 0.22    | 0.51   | 0.63   | 0.54   | 0.57       |
| Deceleration (m/s²) | -0.62| -0.36 | -0.37   | -0.58  | -0.75  | -0.79  | -0.65      |
| Accelerationmax (m/s²) | 0.83 | 1.53  | 0.67    | 1.48   | 1.06   | 1.06   | 0.79       |
| Decelerationmax (m/s²) | -0.28| -0.11 | -0.06   | -1.48  | -0.83  | -1.39  | -0.83      |
| PKE (m/s²)         | 0.720 | 0.870 | 0.660   | 0.350  | 0.578  | 0.220  | 0.412      |

4. Conclusion

The main purpose of a driving cycle is to react as a standard for a place or area for routing condition. Based on this driving cycle, it can be used to other researchers to do analysis and automotive simulation referring to this cycle by determined rate of emissions and fuel consumption for road conditions, vehicle type and behavior of different populations in each place. BPDC was developed to represent the Batu Pahat driving cycle pattern The Batu Pahat Driving Cycle (urban) (BPDCu), Batu Pahat Driving Cycle (rural) (BPDCr) and UTHM Driving Cycle (UTHMDC), there are significant differences between these three graph cycle. The graph for BPDCu velocity fluctuations, while BPDCr, and UTHMDC were smooth and uniform velocity. This is due to the difference of congestion and traffic conditions. From the results of calculations on data such as the average acceleration of the driving cycle, the average deceleration, and PKE is not the same as the existing drive cycle. This is
due to different condition driving cycles. Overall, the objectives of the study have been achieved with a developed system of driving cycles to represent an area of Batu Pahat. From Batu Pahat driving cycle, it may be used as a reference for the area in order to determine the emission rate and fuel consumption in other research.

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