Driving Cycle Generation for Emissions and Fuel Consumption Assessment of the Motorcycles in Khon Kaen City

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Abstract

In this paper, the generating of driving cycle for emissions and fuel consumption assessment of the motorcycles in Khon Kaen city is presented. The driving cycle was obtained from on-road traffic data collections, using the speed-time data logger to collect data during weekday and weekend under actual traffic along the selected road routes in Khon Kaen urban area for one month. To represent real driving pattern of the motorcycles in Khon Kaen city, the driving cycle was generated from several micro-trips which was selected in order to matching with defined target parameters of the real speed-time data. The driving cycle was categorized into three traffic conditions on weekday, weekend and combined weekday-weekend periods by the statistical method. The results show that Khon Kaen driving cycle has a cycle length of 1145 s with total percentage error in the target parameters of 12.01%

Key words: Driving cycle; Motorcycle; Micro-trip

1. Introduction

Estimations of the exhaust emission and fuel consumption of a vehicle can be determined from some design parameters with an assumption that the engine operates at average condition obtained from traffic data. A possible and practical way is to establish a driving pattern, which can represent the driving characteristic for any vehicle traveling in the traffic. This driving pattern is so-called “driving cycle” which provides the variation of the vehicle speed with time for a certain period of travel [1].

A driving cycle which is a representation of a speed–time sequenced profile developed for a specific area or city is widely used to estimation driving behavior, air pollutant emissions, and fuel consumption. Many researchers developed driving cycles for dynamometer vehicle emission testing. Standard driving cycles, such as the US Federal Test Procedure (FTP) and Economic Commission for Europe Cycle (ECE) have been widely used to test vehicle compliance to statutory emission limits as well as for the engine design [2]. Traffic engineers require driving cycles in the design of traffic control systems and simulation of traffic flows and delays. Environmentalists are concerned with the performance of the vehicle in terms of the pollutants generated, while negotiating specific driving patterns [3]. Furthermore, driving cycle can provide a convenient laboratory-based means to estimate fuel consumption and emissions of vehicles within the respective urban areas [4].

There are many driving cycles developed elsewhere under specific driving characteristics which clearly differ from one area to another. For example, use of the European test cycle to predict total exhaust emissions in Turkey did not produce accurate results [5]. The comparison of the driving cycles for Chinese cities with ECE and FTP cycles suggests that the driving patterns in China are a lot different from those in the US and European. Consequently, emission factors produced from the ECE cycle or FTP-based tests would be different than those from the situation in China [6]. Results of motorcycle driving cycle in the Kaohsiung metropolitan area of Taiwan indicated the exhaust emission factors of the Kaohsiung driving cycle were significantly higher than those of the ECE and other cycles [7]. These emphasize the importance of applying driving cycles that can represent real traffic situation in vehicle emission evaluation-related studies for the area concerned.

Therefore, to support further research about optimal driving cycle design and development of an emission factor for a motorcycle in Khon Kaen city, a driving cycle will be generated in this research in order to assessment of the exhaust emissions and fuel consumption of motorcycles in Khon Kaen city.

2. Methodology

Driving cycle for Thailand was first developed in 2004 by Tamsanya et al. [8] with a gasoline passenger car traveling through the urban areas of Bangkok, which is a methodology used as guideline to develop a driving cycle in this study. The driving cycle is developed from micro-trips, which are many small trips separated by idle speed in the collected speed-time data. The uniqueness of this methodology is that the driving cycle is generated considering nine target parameters of the speed-time profile namely, average speed (V_{avg}), average running speed($V1_{avg}$), time spent in acceleration (%Acc), time spent in deceleration (%Dec), time spent at idle (%Idle), time spent at cruise (%Cruise), average acceleration (Acc_{avg}), average deceleration (Dcc_{avg}) and positive acceleration kinetic energy (PKE). Although the presented method using in this study is quite similar to methodology for generated driving cycle in Bangkok. However, estimation of the recalculate probability in updated micro-trips database in this study was eliminated (see section 3.). The steps involved in this methodology are: road routes selection, collection of driving data (speed–time), data analysis, and generation of driving cycle. The steps are given below.

2.1 Road Routes Selection

Khon Kaen City has been selected as study area since there are a huge number of motorcycles traveling in Khon Kaen City and also a high percentage of mode sharing, about 30% of mode share [9]. Rather than Bangkok, Khon Kaen city is one of regional provinces that has currently encountered with traffic congestion problem, especially on peak hours.

The route for collecting driving cycle will be selected from the road network of Khon Kaen urban area in 2008 by method proposed by Tamsanya et al. [10].Traffic flow model was used to determine the travel speed along the route from vehicle traffic flow data on that route. road routes for conducting real driving tests to collect the driving characteristics (i.e. speed versus time data) of vehicles. The driving characteristics will be later used for construction of the driving cycle of vehicles traveling in the city.

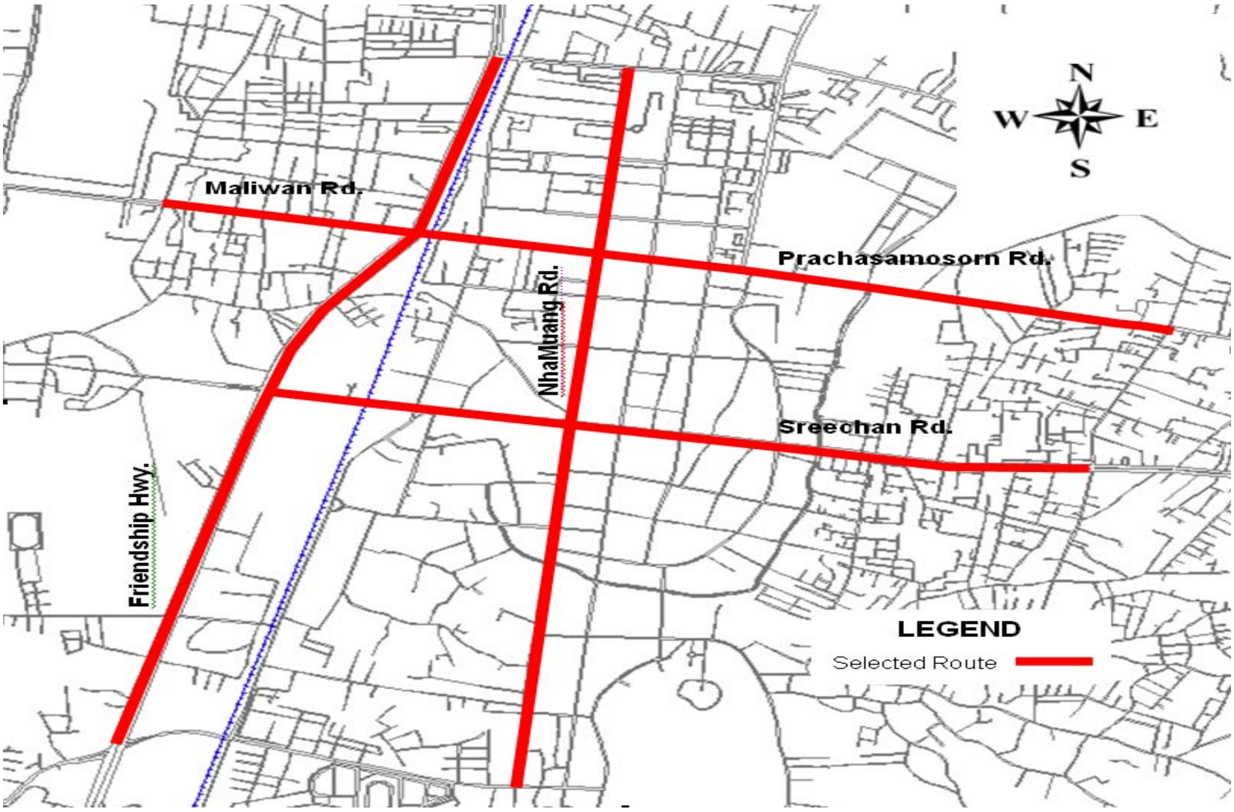


Fig. 1 Routes for data collection

The traffic flow data is given in 2008 by the project of Khon Kaen transit [9]. Ascending these travel speeds determined for all road sections of all major road routes, the distribution of travel speeds of vehicles in the area can then be established as shown in table 1. To select a few major road routes which their distribution of vehicle speeds of all road sections along those selected major roads is closely matched to that of the whole major roads previously established. The matching can be justified by some statistical parameters e.g. variances and mean. These few major road routes can be used as representative

By using the method as described above, the main routes have been selected in according with 3 criteria, matching with range of travel speed (LOS), relatively high traffic volume as well as high choose route for routine commute. The selection result is presented in Table 1. The 3.9 km section of Friendship Hwy. has been selected due to a representative of urban route with travel speed over 40 km/hr as well as high traffic volume. The 3.0 km section of Sreechan Rd. has been selected as being a representative route with 30-39 km/hr travel speed and high traffic volume. The 3.8 km

Table 1. Selected Routes for On-road Data Collection

No.	Selected Route	Distance (km)	Range of Travel Speed, km/hr (LOS)	Traffic Volume*, PCU (V/C)	Range of Most Choice Route**
1.	Friendship Hwy.	3.9	$\geq$ 50 40 – 49	1,737 (0.40)	2
2.	Sreechan Rd.	3.0	30 – 39	1,235 (0.66)	1
3.	NhaMuang Rd.	3.8	20 – 29	920 (0.62)	6
4.	Prachasamosorn Rd.	2.8	15 – 19 $<$ 15	1,054 (0.7)	3
5.	Maliwan Rd.	1.0	15 – 19 $<$ 15	2,149 (0.68)	5

Note: * Traffic volume during morning peak hour (7:30-8:30 AM)

** Result from interviewing 85 samplers form 35 communities by questionnaire

section of NhaMuang Rd. has been selected as being a representative route with 20-29 km/hr travel speed. The 2.8 km section of Prachasamosorn Rd. and 1.0 km section of Maliwan Rd. have been selected as being a representative route with travel speed under 20 km/hr. Thus, total route distance for on-board data collection is 14.5 km. Their specific routes are displayed in Figure 1.

2.2 Data Collection System

The vehicle used in this study is a Yamaha Fino, which is a four-stroke motorcycle with engine capacity of 113 cc. It was selected because of its highest number of register in Khon Kaen city.

The speed-time data collection will be carried out using a real time logging system equipped on a selected motorcycle traveling

Table2. Target Parameters used to characterize driving cycles in this study

Parameter	Symbol	Meaning
Average speed	V_{avg}	Average speed in a cycle, including idle periods
Average running speed	$V1_{avg}$	Average speed in a cycle, excluding idle periods
Time spent in acceleration	%Acc	Fraction of time accelerating for ≥ 0.27 m/s^2
Time spent in Deceleration	%Dec	Fraction of time decelerating for ≤ 0.27 m/s^2
Time spent at Idle	%Idle	Fraction of time having zero speed
Time spent at Cruise	%Cruise	Fraction of time having absolute speed changes ≤ 0.27 m/s^2
Average acceleration	Acc_{avg}	Rate of change of speed above 0.27 m/s^2
Average deceleration	Dcc_{avg}	Rate of change of speed below - 0.27 m/s^2
Positive kinetic energy	PKE	Positive acceleration kinetic energy

along the route under actual traffic. This speed-time data logger can display and record the vehicle speed every second. Calibration of data logger will be done before launching the selected vehicle to collect speed-time data. In the calibration, the average travel speed from data logger will be compared with the referenced average travel speed that will be obtained from travel time from standard stopwatch and known distance path. The speed-time data in this study will be collected during the morning peak between 7:00 a.m. and 9:00 a.m. on January 2010. Such the speed-time data collections are carried out on Monday - Friday to represent the heavy congested traffic condition of weekday. For the weekend traffic conditions, the data collections are carried out on Saturday or Sunday.

2.3 Data Analysis

To determine the target driving parameters for Khon Kaen city, the collected data from all selected road routes are summed and analyzed. The target driving parameters are generally accepted as the indicators of the actual on-road driving situations. They will be used as the criteria in the process of driving cycle generation. The detailed descriptions of the target parameters have been provided in Table 2.

The results of the target driving parameters determined from the speed-time data on each road route during weekday and weekend periods are shown in Table 3 and 4 the length of each road route in kilometers is

Table3. Driving parameters of selected road routes during weekday period

Route	Distance (km)	V_{avg} (km/h)	$V1_{avg}$ (km/h)	Acc_{avg} (m/s^2)	Dec_{avg} (m/s^2)	Idle (%)	Cruise (%)	Acc (%)	Dec (%)	PKE (m/s^2)
1: Friendship wy.	3.9	30.654	39.185	0.673	-0.686	21.159	16.754	31.338	30.749	0.466
2: Sreechan Rd.	3	21.427	28.217	0.696	-0.723	23.119	14.308	31.840	30.662	0.525
3: NhaMuang Rd.	3.8	23.216	27.838	0.592	-0.676	15.875	18.396	35.033	30.696	0.443
4: Prachasamosorn + Maliwan Rd.	3.8	21.724	27.427	0.670	-0.676	19.805	16.371	32.038	31.786	0.488

Table4. Driving parameters of selected road routes during weekend period

Route	Distance (km)	V_{avg} (km/h)	$V1_{avg}$ (km/h)	Acc_{avg} (m/s^2)	Dec_{avg} (m/s^2)	Idle (%)	Cruise (%)	Acc (%)	Dec (%)	PKE (m/s^2)
1: Friendship Hwy.	3.9	34.812	44.751	0.656	-0.709	21.574	19.494	30.618	28.313	0.423
2: Sreechan Rd.	3	24.639	32.342	0.679	-0.759	22.980	14.753	32.878	29.389	0.513
3: NhaMuang Rd.	3.8	26.336	31.656	0.578	-0.675	16.147	20.311	34.227	29.315	0.414
4: Prachasamosorn + Maliwan Rd.	3.8	27.347	32.992	0.694	-0.740	16.199	18.202	33.851	31.748	0.475

also given in the tables. From the weekday results in Table 3 Sreechan road has the heaviest traffic congestion. It has the lowest value of average speed of 21.427 km/h with highest time spent at idle of 23.119%. Comparisons of weekend driving parameters shown in Table 4 to those obtained from weekday indicate the tiny different driving situations. The results of the target parameters determined for Khon Kaen under three categories (i.e. weekday, weekend and combined weekday-weekend) are shown in Table 5. It is observed that the target parameters between weekday and weekend are not distinctly different. The values of the target parameters are very close. Therefore, this study is generated driving cycle to represent the driving pattern in traffic conditions on combined weekday and weekend periods.

Table 5. Target parameters of driving characteristics of Khon Kaen traffic under three categories (weekday, weekend and combined weekday-weekend)

Target parameters	Weekday	Weekend	Combined Weekday-Weekend
V_{avg}, km/h	24.195	28.256	25.304
$V1_{avg}$, km/h	30.527	35.290	31.837
Acc_{avg}, m/s^2	0.655	0.649	0.653
Dec_{avg}, m/s^2	-0.690	-0.720	-0.698
%Idle	19.926	19.176	19.721
%Cruise	16.494	18.237	16.970
%Acc.	32.634	32.915	32.710
%Dec.	30.947	29.672	30.599
PKE, m/s^2	0.478	0.452	0.470

2.4 Driving Cycle Generation

The approach to the generation of the driving cycle used in this study is based on building up a series of micro-trips randomly selected from the database containing a large number of real micro-trips analyzed from the on-road collected speed-time data. Fig. 2 shows example of eight micro-trips. A micro-trip is defined as the sequence of driving data between successive stops in the trip.

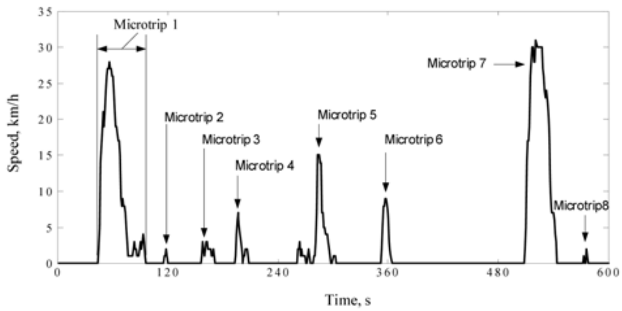


Fig. 2 Example of micro-trips [8]

The computer program will extract the desired micro-trips from the real micro-trip database, which are classified into five speed ranges as, between 0 and 10 km/h, more than 10 to 20 km/h, more than 20 to 30 km/h, more than 30 to 40 km/h and more than 40 km/h. These speed ranges are chosen with an equal probability by the random number generated by the computer during the cycle simulation process. Similarly, in the selection of a micro-trip from any speed range, each micro-trip in the range is given an equal probability that can be calculated based on the number of micro-trips in the range. To commence the driving cycle generation, the program will first generate a random number to select the speed range, and then another random number to select a micro-trip from the selected speed range. The values of target driving parameters of the selected micro-trip are calculated and compared with the corresponding target parameters prior to selecting the next micro-trip. Whenever a new micro-trip is selected and added to the previously selected ones to form a new set of micro-trips. The entire procedure is repeated until the desired running duration of the cycle is reached. The desired running duration of the cycle is the total driving cycle duration minus the idle duration. The total duration of the driving cycle is considered based on the fact that it should be long enough to describe all traffic situations and should sufficiently characterize the emissions. Therefore, the duration of the total driving cycle is set at 1200 seconds, which is within the range used by various well-known driving cycles based on the time necessary to sample enough for analysis. The idle duration of the cycle is calculated in proportion to the percentage of idle duration of the real on-road driving data. Finally, equal idle periods, which are determined by dividing the idle duration by the number of selected micro-trips, are inserted between the micro-trips, forming the driving cycle. The procedure of the program is described by the flow chart shown in Fig. 2.

Many driving cycles were developed and the best cycle was finally selected with minimum total percentage error in the target parameters.

3. Results

The driving cycle generation procedures described above are applied to the on-road driving data collected from the five selected road routes of Khon Kaen city. The obtained driving

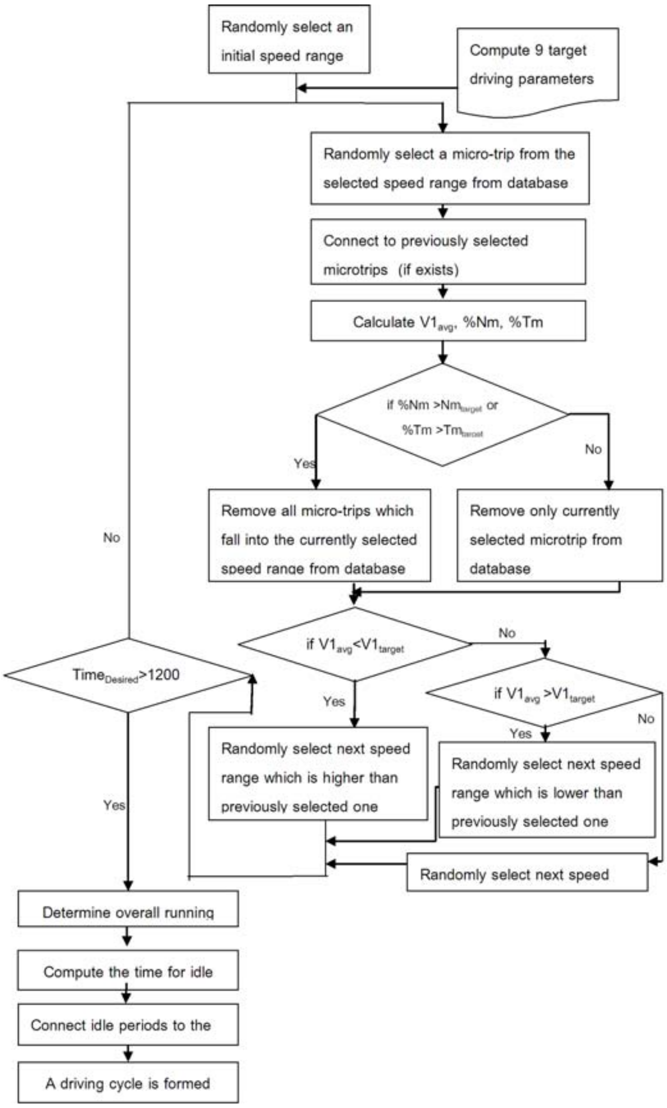
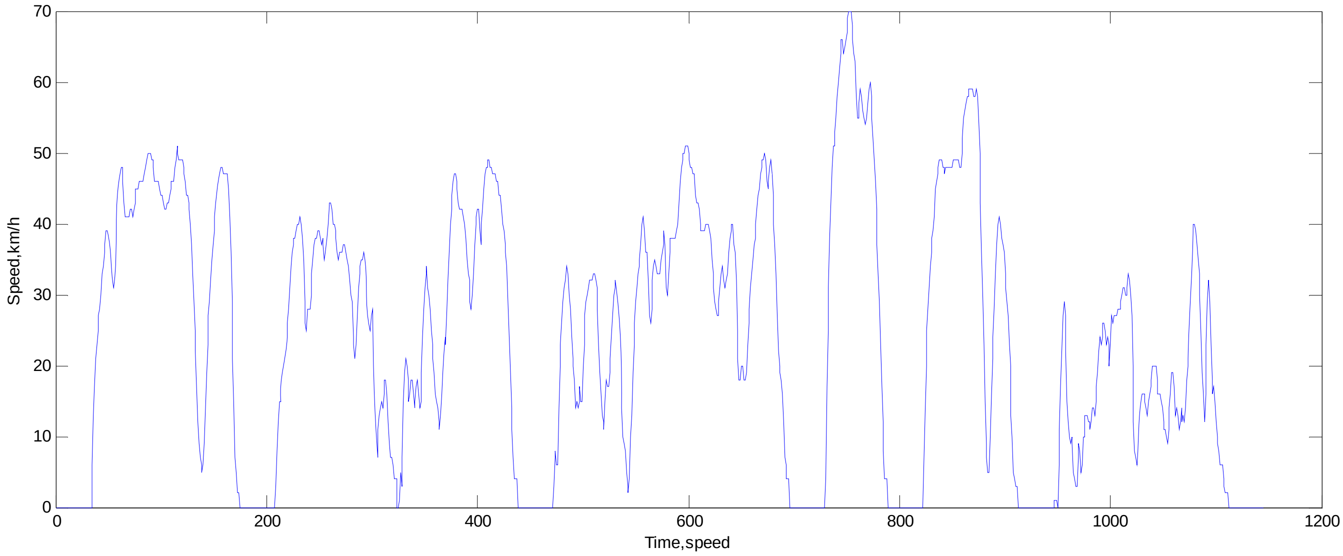


Fig. 2 Flow chart for generating a driving cycle

parameters of Khon Kaen driving cycle are closest to target parameters as shown in Fig. 3. The cycle is 7.647 km in length, 1145 s in time duration and involves 6 intermediate stops. Driving characteristics are found to be in good agreement with the Khon Kaen target driving parameters previously discussed in Section 2.3 with total percentage error in the target parameters of 12.01%



V_{max} =70 km/h; Acc_{max} = 3.61 m/s^2 ; Dec_{max} = -2.22 m/s^2 ; length 1145 s; distance = 7.647 km

Fig. 3 Khon Kaen driving cycle

4. Conclusion

Generation of driving cycle is necessary for assessment of emission and fuel consumption. The Khon Kaen motorcycle driving cycle was developed from speed-time data collected for one month across the five selected routes using a data logger. The methodology for generation of driving cycle also described in this study. The methodology concerns with consider the important parameters of the speed-time data namely, average speed, average running speed, time spent in acceleration, in deceleration, at idle, at cruise, average acceleration, average deceleration and positive acceleration kinetic energy with minimum percentage error in the target parameters. Therefore, this approach is expected to be a better representation of Khon Kaen driving pattern.

5. Acknowledgement

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