

Driving Cycle for Motorcycle Using Micro-Simulation Model*

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ABSTRACT

Driving cycle of vehicle has been used in emission estimation and fuel consumption study. Existing method of data collection using car chasing technique is expensive. The technique using micro simulation approach is cheaper and fast to derive the driving cycle. In this paper a traffic simulation model Driving Cycle Micro-Simulation Model for Motorcycle has been developed. The issue of lateral and longitudinal movement aspect in motorcycle driving has been examined in the model. Parameters to cover such movement have been built in the model and applied on a stretch in Edinburgh city of Scotland. Results from model have been both calibrated and validated. The results show that Driving Cycle Micro-Simulation Model for Motorcycle gives better representation of driving cycle and it can be used to understand the effect of driving modes on emission for better understanding of vehicular emission control.

Keywords: Micro-Simulation; Driving Cycle; Vehicular Emission; Motorcycle

1. Introduction

This Traditional chase car method, and on board method for data collection of driving cycle are expensive in nature [1]. Traffic micro-simulation models can simulate/represent individual driver behavior and the real world driving cycles in laboratory for vehicles and roads in cost effective manner using secondary data [2]. Modelling individual driving cycle for motorcycle is done by simulating the speed of vehicles second-by-second basis. In this paper, Driving Cycle Micro-Simulation Model for Motorcycle (DCMSMM) for a section of urban network in Edinburgh has been developed. Its calibration and validation has been done using different sets of real-world data of driving cycle of Edinburgh Motorcycle Driving Cycles (EMDC) and results of DCMSMM have been compared with published parameters of EMDC [1] and corresponding emission factor (EF) are evaluated.

2. Model Building

2.1. Selecting a Parameters for Model Development

In most of the microscopic traffic simulation model, longitudinal dynamics of single vehicles parameters influence the model. But, the movement of motorcycles is a two-dimensional movement *i.e.* longitudinal and lateral movement. The longitudinal movement contributes to

forward movement and lateral movements are used to take up appropriate positions. Motorcycles can get more longitudinal gap to accelerate their speed by lateral movements [3]. In another case study of Edinburgh driving cycle for motorcycle of Gorgie Road of 1.01 km length having signal free section were developed by Kumar [4]. They investigated simulation of motorcycle driving behaviour and found the average speed 17.37 km·h⁻¹, proportion of idling time 35%, and time spent in proportion of acceleration was found to be 35.8%.

However the results were neither calibrated nor validated. But this case study was good application of micro-simulation approach to develop driving cycle for motorcycles.

In this paper VISSIM 5.10 has been used for simulation and additional required parameters have been created to derive the speed-time sequence representing driving cycle for motorcycle. The motorcycle traffic flow is influenced by driver characteristics, vehicle interactions and the external environment, all of these the proposed model DCMSMM are taken into account. The vehicle interactions such as longitudinal and lateral movements, external environment as creation of motorcycle lanes near the stop line for its stopping in front are considered in model building.

2.2. Inputs for DCMSMM

There are four required input *i.e.* traffic signal, road-net-

*Micro-simulation based driving cycle derivation for motorcycle.

work, driver behaviour and vehicular characteristic and behaviour characteristics to create the microscopic motorcycle driving cycle model. The detailed driver behaviour look ahead distance, the maximum distance allowed for looking ahead, the minimum value minimum look ahead distance, the observed vehicles and look back and other parameters gap, headway etc. are exclusively needed to model lateral vehicle behaviour (**Table 1**). Routes and nodes are created on existing routes. Database of traffic video, signal time and traffic flow for 21 intersections for section of the AQMA area of Edinburgh is developed and used as input to simulate driving cycle. Parking lots are created to start the point at Morningside-Holy Corner road to end point at Broughton Street for simulation run of motorcycle. Range of relevant traffic parameters such as driving behaviour parameters, simulation parameters such as random seeds, time scale are extracted from database and used for further analysis and model calibrations, till simulation results are stabilised.

The following factors are considered as assumption in

modelling while comparing with real world driving cycle 1) Geographical characteristics of modelled corridor 2) Length of the corridor 3) Type of engine size 4) Driving behaviour 5) Signal control 6) Time of survey 7) Traffic assignment. **Table 1** shows requisite changes made in simulation parameters of driving behaviour for motorcycles to generate motorcycle driving cycles. Finally simulation models are run with simulation resolution of 1-Second and with different random seeds.

2.3. Characteristics of Study Area

Series of micro simulation runs were made along Edinburgh AQMA corridor (**Figure 1**). The test track covered nineteen traffic signals (one 5-arm, seven 4-arm and ten T-junctions). The speed limit is $48 \text{ km}\cdot\text{h}^{-1}$ along the corridor and total percentage of motorcycle traffic varies from 1% - 3% of the total fleet. The part of test track is used for developing the driving cycle for motorcycles-EMDC [1]. GPS based data acquisition system was installed in

Table 1. Change in default simulation driving behavior parameter for urban and motorcycle lane.

Driving behavior	Simulation parameters	Parameters	Urban lane	Motorcycle lane	Reason
Car-following	Look ahead distance (m)	Maximum value	0	5	Required more distance because of less height and less sight distance
		Minimum value	250	250	
	Observed vehicle		4	2	Due to con-strained sight ahead
		Look back distance (m)	Maximum value	0	
Necessary lane changes	Temporary lack of attention (Sec)	Minimum value	150	150	
			0	0	
	Maximum deceleration m/sec^2	Trailing vehicle	-3	-3	
		Own	-2	-3	
	-1 $\text{m}/\text{sec}^2/\text{distance}$	Trailing	10	25	
		Own	10	25	
Accepted deceleration (m/sec^2)	Own	-1	-1		
	Trailing	-1	-1		
Lateral	Waiting time before diffusion		120	60	Gipps (1990)
	Maximum deceleration for cooperative braking		-2	-3	It has more power mass ratio to control
	Desired position of free flow		Middle of lane	Any	
	Overtaking on same lane		Not allowed	Yes both on left and right	
Signal control	Minimum lateral distance	Distance (m) at $0 \text{ km}\cdot\text{h}^{-1}$	1	0.5	It need less space to filter into traffic
		Distance (m) at $50 \text{ km}\cdot\text{h}^{-1}$	1	1	
			Default	Default	

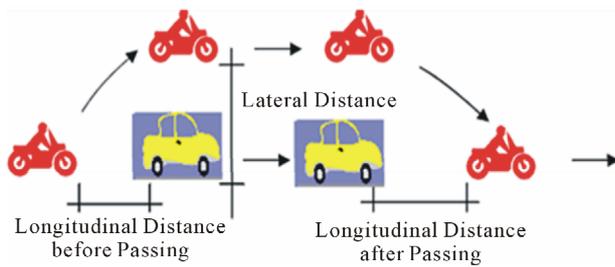


Figure 1. Passing maneuvers of motorcycles.

motorcycle for field data collection for calibration and results validation. Signal cycle length significantly affect the cycle time of driving cycles, their phase wise data were collected to build the model.

2.4. Calibration and Validation of DCMSMM

Calibration and validation of driving cycle simulation model for motorcycle is done by GEH technique [5-7] which is frequently used by Directorate of Traffic Operations (DTO) in UK [8]. GEH value of 5 indicates a good level of threshold reliability and The GEH statistic is standard measure of the “goodness of fit” between observed and modelled flow. The GEH is calculated as follows in “Equation (1)”

$$\sqrt{\frac{(M - C)^2}{(M + C)/2}} \quad (1)$$

where M and C are the modelled and observed speed (% frequency) respectively.

Smaller GEH values indicate a better “fit” between observed and modelled speed [8]. **Table 2** shows the GEH values for the reliability indicator. Two data sets are compared; real world speed and the modelled speeds from simulation model. Observed speeds from both real world and DCMSMM are categorized into seven categories for speed ranges between 0 - 60 km·h⁻¹. The GEH statistics are applied on the results from simulation. Four values of random seeds were used for GEH statistical goodness of fit. Different random seeds are considered in simulation run. The corresponding speed frequency by changing the value of random seeds (90, 30, 50, and 10) is estimated. The speeds are found in the range of 0 - 10 km·h⁻¹ and 10 - 30 km·h⁻¹ which is lower than the real-world driving speed. The real world driving cycle’s speeds are found to be distributed in the range of 0 - 20 km·h⁻¹ and 30 - 69 km·h⁻¹. Little deviation between real world and micro-simulation approach is observed. Models with the same number of random seeds and input files have the same result, but the different random seeds with same input files will have different result and vice versa, because random seeds affect the realization of the stochastic quantities in simulation such as inlet flows and

vehicle capabilities.

2.5. The Model Outputs

The output files from micro-simulator run are recorded for each vehicle’s actions. DCMSMM provide the instantaneous speed data at intervals of 1 second or 0.1 second for each individual vehicle. In data analysis, simulation resolution is assigned one second to create the smooth driving pattern. The final value of random seed is selected when simulated results get stabilize. **Figure 2** shows simulated speed of DCMSMM, which is able to reproduce the real-world speed time sequence of the motorcycle driving cycle. The model outputs are integrated with National Atmospheric Emission Inventory (NAEI) database to estimate emission. The instantaneous speed from micro-simulation approach is useful to estimate the emissions in the absence of on-board measurement or laboratory measurement.

3. Results and Discussions

3.1. Characteristic of DCMSMM

Table 3 present comparisons of characteristics of the DCMSMM with Edinburgh Real World Motorcycle Cycle Driving Cycle-EMDC [1]. A large proportion of the DCMSMM cycle time is found in cruising while time spent in idling time is relatively small. The average cycle speed over the whole driving cycle ($V1$) is 14.4 km·h⁻¹, while the average running speed ($V2$) is 18.22 km·h⁻¹. Average acceleration is 0.65 ms⁻², while average deceleration is 0.556 ms⁻². The mean length of driving period is 1010 second (around 16 minutes). Total driving length is 4.1 km. It should be noted that micro-simulation based methodology is highly sensitive and needs many parameters for calibration and validation. The more parameters are available for the calibration of driving cycle, the higher the accuracy would be. However, the comparison should be taken with great care, since there are a number of assumptions, affect the accuracy of the results. **Table 3** present the value of assessment parameters of EMDC and simulated driving cycles.

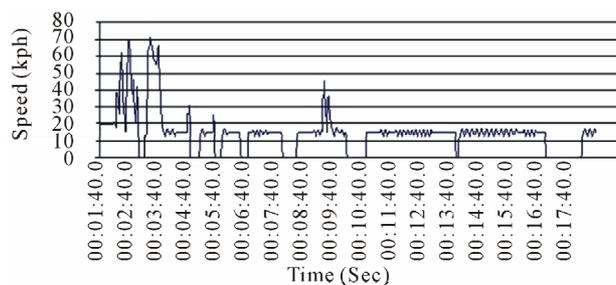


Figure 2. Simulated driving cycle of motorcycle for Edinburgh AQMA.

Table 2. GEH value for calibration of micro-simulation model.

Random Seeds	Speed (km·h ⁻¹)	Frequency (Fi)	Modelled (M)	Observed (C)	(M - C) ²	[M + C]/2	GEH = $\sqrt{\frac{(M - C)^2}{(M + C_2)/2}}$
90	0	208	20.59	2.27	335.91	11.43	5.42
90	10	19	1.88	34.42	1058.73	18.15	7.64
90	20	683	67.62	12.32	3058.18	39.97	8.75
90	30	29	2.87	18.27	237.18	10.57	4.74
90	40	21	2.08	18.56	271.46	10.32	5.13
90	50	15	1.49	11.33	96.95	6.41	3.89
90	>60	35	3.47	2.83	0.40	3.15	0.36
		Sum Total 1010			Average GEH Value 5.13		
30	0	212	16.91	2.27	214.32	9.59	4.73
30	10	40	3.19	34.42	975.28	18.80	7.20
30	20	959	77.35	12.32	4228.84	44.84	9.71
30	30	26	2.07	18.27	262.39	10.17	5.08
30	40	3	0.24	18.56	335.48	9.40	5.97
30	50	2	0.16	11.33	124.81	5.75	4.66
	>60	1	0.08	2.83	7.58	1.46	2.28
		Sum Total 1243	C		Average GEH Value 5.66		
50	0	194	15.47	2.27	174.35	8.87	4.43
50	10	28	2.23	34.42	1035.97	18.33	7.52
50	20	823	65.63	12.32	2841.64	38.98	8.54
50	30	83	6.62	18.27	135.80	12.45	3.30
50	40	5	0.40	18.56	329.66	9.48	5.90
50	50	2	0.16	11.33	124.81	5.75	4.66
50	>60	1	0.08	2.83	7.58	1.46	2.28
Sum Total		1136			Average GEH Value 5.23		
10			Average GEH Value		4.85		

3.2. Comparison of Driving Cycle Parameter for Simulated and Real World

The average speed (V1) and average running speed (V2) in the simulated driving cycle are found to be nearly half that of the real-world driving cycle. The total cycle duration is from 1010 seconds in the simulated driving cycle where as it is 770 second in real-world EMDC. Time is spent in idling for DCMSMM is found higher in city centre. Therefore, cycle time of the real world and the simulated cycles is different. Time spent in idling is found 18% of the total cycle time, which deviates noticeably from the real-world value (1.5%). The percent-

age of time spent in acceleration is found to be 24% as compared to 44.5% in the EMDC. In contrast, percentage of time spent in deceleration for DCMSMM simulated is 28% as compared to 46.87% in the EMDC. However, the cruising proportion of the EMDC is found to be 7.24%, extremely low compared to 29.45% for the simulated cycle. In simulated system, there is no representation of the SCOOT system and real world assignment of traffic volume on all the arms, therefore the results deviate strongly. The number of changes in acceleration and deceleration in one driving period in simulation is found to be much lesser than the real-world cycle, which indicates that drivers are sensitive to the traffic, signals, and other

Table 3. Characteristics of driving cycle.

Sr. No.	Assessment Parameter	Value from Simulated DC	Value from Edinburgh Motorcycle Driving Cycle (EMDC)
1	Average deceleration of all deceleration phases (ms^{-2}) (d)	0.56	2.59
2	Average acceleration of all acceleration phases (ms^{-2}) (a)	0.66	1.28
3	Average Speed of the entire driving cycle ($\text{km}\cdot\text{h}^{-1}$) (V1)	14.56	33.5
4	Average Running Speed ($\text{km}\cdot\text{h}^{-1}$) (V2)	18.22	38.85
5	Mean length of driving period C (sec) (C)	1010.00	769.63
6	Time proportion of driving modes in idling (fraction of time spent at speed of 0 - 3 $\text{km}\cdot\text{h}^{-1}$) (Pi) %	18.32	1.51
7	Time proportion of driving modes in acceleration ($a > 0.1 \text{ ms}^{-2}$) (Pa) %	24.06	44.45
8	Time proportion of driving modes in deceleration modes ($d < 0.1 \text{ ms}^{-2}$) (Pd) %	28.61	46.87
9	Time proportion of driving modes in cruising modes ($a \leq 0.1 \text{ ms}^{-2}$, $d \leq 0.1 \text{ ms}^{-2}$) (Pc) %	29.41	7.24
10	Average number of acceleration and deceleration changes within one driving period (M)	58.00	1251
11	Root Mean Square Acceleration (RMS)	0.73	7.83
12	Positive Kinetic Energy (ms^{-2}) (PKE)	44.22	2.81
13	Total driving length (m) (L)	4083	7313.59

factors in the real world [1,9,10].

3.3. Effect of Driving Modes on Emission

The quantities and composition of emission product from vehicles depend on the mode of driving (See **Table 4**). Normally, when the test vehicle starts from the cold, the fuel enrichment increases in choke that provides an easily-combustible mixture near the spark plug. It happens due to slow vaporization of fuel. However, nitric oxide concentration during these modes is low because of low temperature and scarcity of oxygen in the engine. The four modes of driving have been classified 1) time spent in acceleration 2) time spent in deceleration 3) time spent in cruise 4) time spent in idling based on the parameters defined in Tong *et al.* [11]. The simulated driving cycle has 18.46% of time spent in idling. Time spent in deceleration and acceleration is almost equal. There is increase in emission factors during cruising mode except in the case NO_x . HC emission factor is in the range of 1.67 gm/km and CO_2 is found in the range of 148 to 152 gm/km . NO_x emission factors are lowest with 0.302 to 0.2 $\text{gm}\cdot\text{km}^{-1}$. CO emission factor is found between 26.49 to 26.0 $\text{gm}\cdot\text{km}^{-1}$. The average value of CO, HC and NO_x emissions ($\text{gm}\cdot\text{km}^{-1}$) for the 1000 cc engine are estimated 26.7, 1.72 and 0.283 $\text{gm}\cdot\text{km}^{-1}$ respectively, whereas CO, HC and NO_x emissions ($\text{gm}\cdot\text{km}^{-1}$) for 600 cc are 10.581, 1.90 and 0.283 $\text{gm}\cdot\text{km}^{-1}$ respectively. All three pollutants showed higher value than existing regu-

latory standard. EF of HC is found to be higher than simulated EF whereas EF of NO_x for 600 cc engine shows extremely higher even more than Euro 1 standard. Such event can be attributed to induction of Extra Urban Driving cycle in Euro 2 engine size unless NO_x catalyst is not activated.

4. Conclusion

Driving Cycle Micro-Simulation Model for Motorcycle (DCMSMM) is important in understanding emission in different driving modes. Real time data and simulated driving cycle data are compared. Calibration and validation of DCMSM shows its capability to represent realistic driving cycle. However there are several assumptions made in modeling; such type of exercise is very effective in better understanding the driving behavior of motorcycle. Understanding longitudinal and lateral movement of

Table 4. Observed emission factors from simulated driving cycle using NAEI coefficient.

EF ($\text{gm}\cdot\text{km}^{-1}$)	Average Emission Factor	Maximum	Minimum	Standard Deviation
CO	26.7	40.78	16.52	45.11
HC	1.72	3.09	0.50	0.42
NO_x	0.28	0.83	0.25	0.06
CO_2	151.89	245.14	75.42	25.84

motorcycle and model in computer simulated platform is challenging task because of involvement of many input parameters. The comparison with real world data shows nearby results but assumption made bring attention to modeller for better input parameters and more number of simulation runs.

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