

Chapter 2

Microscopic Traffic Simulation Approach to Evaluate Driving Parameters at Influence Zone of the Intersection



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Abstract In recent decades, rapid urbanization has resulted in an increase in vehicle population, causing traffic congestion, longer travel times and lower average vehicle speeds. Intersections are important parts of the road network because they cause traffic congestion and higher speed fluctuations. To understand driving characteristics related to speed variation at the intersection, the driving cycle is an important concept used for many years. The study focuses on the analysis of driving cycle parameters for an urban intersection. The major driving parameters evaluated for demonstrating the speed characteristics of vehicles are acceleration, deceleration, idle and cruise states at the influence zone of the intersection. The result shows that more than 90% of the time is spent on acceleration and deceleration states, whereas approximately 5% of the time is spent on idle state depending upon the signal operation. To achieve microscopic speed analysis, an influence zone is created in VISSIM to mimic the exact traffic scenario.

Keywords Driving cycle · Acceleration · Deceleration · Idle · Influence zone

1 Introduction

In the road network, intersections are vital elements in terms of their control system and geometric conditions, resulting in frequent acceleration and deceleration. The nature of traffic flow at intersections on urban arterials is described by lane changing and a high level of maneuverability, a result of the interactivity of fast- and slow-moving vehicles. Thus, intersections are considered as an instant source of traffic

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congestions and zones of high air pollution concentration due to the varying speed of vehicles [1]. At intersections, the driver has to reduce speed and sometimes even halt for a longer time with active engines, resulting in high fuel consumption and emissions. The driving cycle of an individual vehicle in the traffic stream at a given roadway section varies significantly, especially at intersections. On the upstream and downstream sides of an intersection, greater speed fluctuation is observed because of traffic bunching and platooning, the intersection control system and actions of turning movement of vehicles. On the upstream side, the vehicle starts decelerating while approaching to intersection followed by idle condition and acceleration on the downstream side [2]. Driving cycles are the representation of the sequential speed-time profile of vehicles [3]. The real-world driving cycle data is further used for the identification of the intersection influence zone, derived from the point of speed declines at the upstream side of the intersection to the speed increases at the downstream side. In the present study, the vehicles' speed is assessed at different intervals (10–50 m) for identifying the accurate location of the influence zone. The present study explains the process of evaluation of the driving cycle and the process of finding intersection influence zone for dominant vehicle class MTW (Motorized Three-Wheeler), motorcycle and car.

With due consideration, the objective of the study is to derive the influence zone at intersections related to the greater speed deviation of vehicles. The main objective of the study is to identify the exact location of the speed, where the vehicle starts decelerating because of the influence of the intersection. Furthermore, the location of the endpoint where the influence of the intersection ends with cruise speed.

The study of Lin et al., 2015 [4] has explained the development of a traffic control system based on vehicular delay and queue length. A regression analysis was carried out to derive the relationship between vehicular emissions and delay. A traffic signal control model is developed to reduce emissions and delay based on vehicle trajectories, which shows significant reductions in emissions. Wolfemann et al., 2011 [5] had developed a model for signalized intersections in Japan using empirical data of vehicle trajectories. The modelling of speed profiles of turning vehicles is carried out and their behaviour is predicted to assess different intersection layout and signal settings. The study of Wang, 2018 [6] highlights the behaviour of driver's speed at the urban signalized intersection. The test vehicle is run in real traffic which records the speed of a vehicle approaching the intersection and crossing the intersection. The eye tracker records the driver's behaviour which is useful for the analysis of the driver's behaviour at the intersections. The study describes that the driver drives at a high speed when far away from the intersection and rapidly decreases the speed while approaching the intersection. The study did not consider the factors affecting driving behaviour like traffic volume, driver's age and driving experience.

2 Study Area and Data Collection

After Ahmedabad and Surat, Vadodara is the third largest city in the Indian state of Gujarat. Rapid urbanization has resulted in population spillover outside of Vadodara’s city limits over time. The high growth of the personal vehicle is projected due to inadequate and less sufficient mass transport system. The city has a gradual increase in paratransit vehicles (Auto rickshaw/MTW) because of the lack of city bus services [7]. MTW is the major contributor to traffic congestion in the peak hour period. The Old Padra road of the city is located in the CBD area considered for exhaustive traffic congestion in peak hour periods due to closely spaced intersections. The speed data has been collected for one of the intersections of the Old Padra road, namely the Ambedkar circle. It is a three-legged signalized intersection. Figure 1 shows traffic view and vehicle composition at Ambedkar circle. The data was collected using a device known as a performance box (Racelogic). The instrument is connected to a battery and a GPS device after mounting on the vehicle. Figure 2 shows driving cycle profiles for MTW, collected through a performance box. The intersection is located at a 3200 m distance from the origin of the data collection.

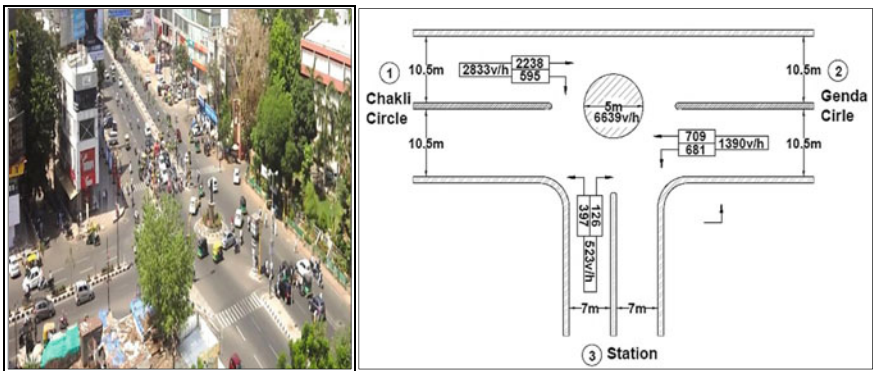


Fig. 1 Ambedkar circle

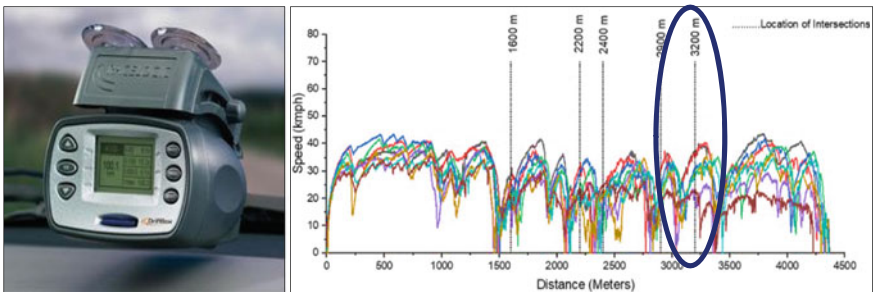


Fig. 2 Driving cycle profile for MTW through performance box

3 Methodology

3.1 Delineation for Influence Zone Identification

It is important to know the driving pattern for different locations to get the start point of speed fluctuation to the point of cruise speed. It is difficult to get the constant speed of the vehicle for a corridor throughout the length in heterogeneous traffic conditions and if the road has a control traffic system. The intersection influence zone is the stretch at which the deceleration mode starts followed by idle and acceleration mode, the stretch ends with the completion of acceleration mode and subsequently, driver achieves his cruise speed. The intersection influence zone is determined by dividing the whole driving cycle data into average speed values. It is difficult to decide the criteria to segregate the whole driving cycle for the identification of accurate influence zone location as it constituents varying driving states near the intersection. To figure out this issue, an analysis was carried out for finding the location where speed is exactly declined due to the influence of intersection. The individual driving cycle involves the speed of a vehicle with a precision of every 0.1 s data. The analysis of data is carried out by enumerating the speed of a probe vehicle at every 10 m, 20 m, 30 m, 40 m and 50 m distances. Different driving cycles have been generated from these average speeds and their pattern is scrutinized. Figure 3 shows the method for identification of location for influence zone. Figure 4 shows the base cycles and relative driving cycles for average speed at 10–50 m distances. The red circle marking indicates the position of the origin point of the influence zone for the intersection for MTW, where exactly the speed starts declining at the upstream side of the intersection (3200 m from the origin).

The average speed of the whole driving cycle for every 10 m, 20 m, 30 m, 40 m and 50 m distances is calculated and respective driving cycles are generated. It is difficult

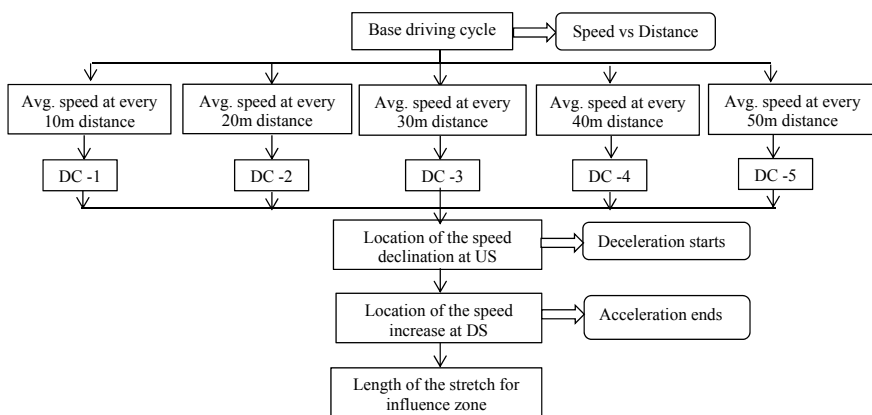


Fig. 3 Method of influence zone identification

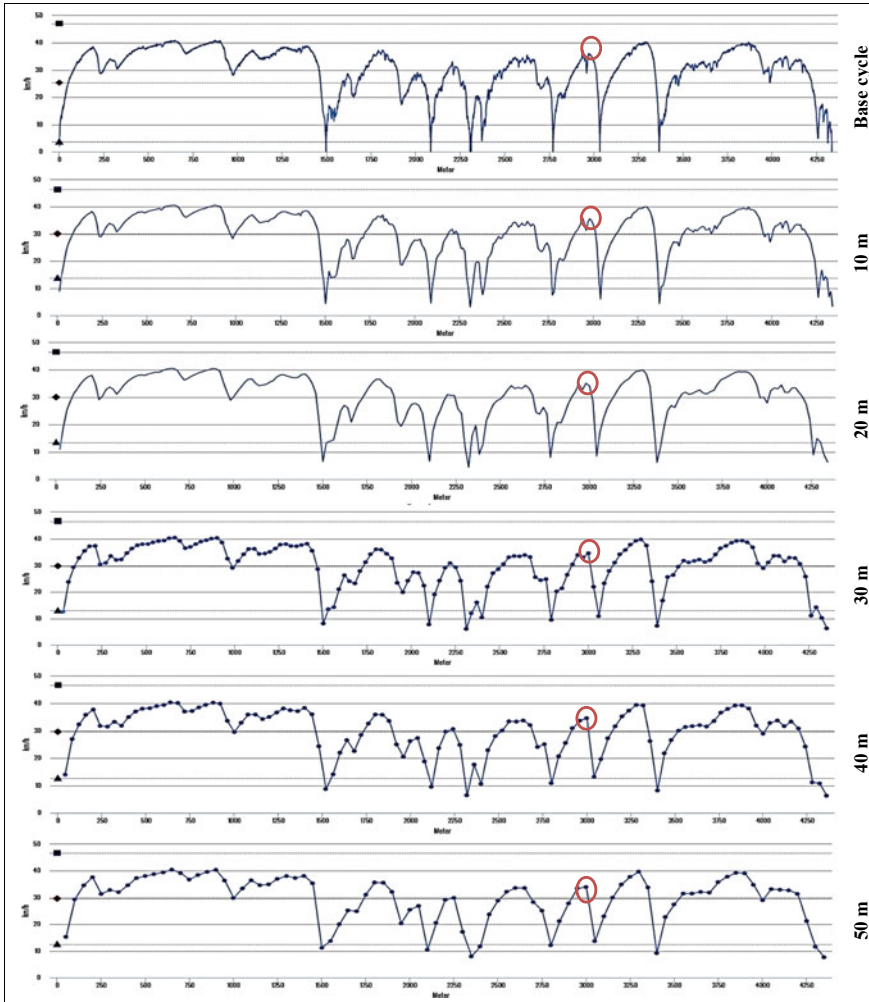


Fig. 4 Base cycle and driving cycle for average speed at 10–50 m distances for MTW

to compute average speed at every 10–50 m distance manually because of enormous speed data. The computer program is generated for finding the average speed at a given distance and generating driving cycles for the relative average speed. The location at which speed starts decreasing (deceleration state) is marked, considered as the original position of the influence zone. Similarly, the end location is also marked where the acceleration state of a vehicle is finished, which is probably found at the downstream side of the intersection. Table 1 shows the position of the origin point of the deceleration state at which speed starts decreasing and acceleration state finishes for MTW. Similarly, the points have been identified for motorcycle and car. It is observed that for all cases of average speed, the location of the origin point of

Table 1 Location of the origin point of the influence zone for MTW

Driving cycle	Deceleration starts at (m)	Acceleration ends at (m)	Average speed (kmph)
DC-1	2993	3230	26.67
10 m	2970	3240	30.80
20 m	2960	3240	30.65
30 m	2970	3240	30.59
40 m	2960	3240	30.33
50 m	3000	3250	30.33
DC-2	2972	3290	25.40
10 m	2980	3300	30.14
20 m	2980	3300	30.05
30 m	3000	3300	29.87
40 m	3000	3280	29.72
50 m	3000	3300	29.62
DC-3	2999	3280	23.95
10 m	3000	3290	30.47
20 m	2980	3300	30.38
30 m	3030	3300	30.13
40 m	3000	3280	30.02
50 m	3000	3300	30.00
DC-4	3029	3284	22.13
10 m	3040	3280	28.89
20 m	3040	3300	28.71
30 m	3030	3300	28.57
40 m	3040	3280	28.30
50 m	3050	3300	28.40
DC-5	2975	3298	19.69
10 m	2980	3300	23.91
20 m	2980	3300	23.81
30 m	2970	3300	23.66
40 m	3000	3320	23.54
50 m	3000	3300	23.30
DC-6	2972	3300	19.68
10 m	2980	3300	24.72
20 m	2980	3300	24.61
30 m	3000	3300	24.41
40 m	3000	3320	24.34
50 m	3000	3300	24.01

(continued)

Table 1 (continued)

Driving cycle	Deceleration starts at (m)	Acceleration ends at (m)	Average speed (kmph)
DC-7	3005	3248	23.64
10 m	3010	3250	26.78
20 m	3020	3260	26.69
30 m	3030	3270	26.53
40 m	3040	3240	26.51
50 m	3050	3250	26.22
DC-8	2956	3322	21.01
10 m	2970	3330	23.07
20 m	2960	3320	22.99
30 m	2970	3330	22.94
40 m	3000	3320	22.92
50 m	3000	3350	22.85



Fig. 5 Length of influence zone at the intersection

the influence zone is similar for all driving cycles. The intersection in the study area is at 3200 m, where the influence zone is marked 300 m before the upstream side and ends at 200 m after the downstream side, marked at 2900 m and 3400 m, respectively. Table 1 shows the length of the stretch used as an influence zone for MTW. Figure 5 shows the length of the influence zone at the intersection site.

3.2 Driving Parameters at Influence Zone

The influence zone is evaluated by calculating mainly four driving parameters; Percentage acceleration (P_a), Percentage deceleration (P_d), Percentage idle (P_i) and Percentage cruise (P_c). Idle driving state is the operation of a vehicle at stationary conditions when the engine is in working condition and significantly responsible for emissions at the intersection area. Cruise speed is the speed at which a driver drives

a vehicle at steady-state condition. Criteria for the calculation of driving parameters are mentioned below [8].

1. Percentage of time spent in acceleration state (P_a)—Acceleration $> 0.1 \text{ m/s}^2$
2. Percentage of time spent in deceleration state (P_d)—Deceleration $< -0.1 \text{ m/s}^2$
3. Percentage of time spent in cruise state (P_c)—Speed $> 5 \text{ kmph}$ and acceleration -0.1 to 0.1 m/s^2
4. Percentage of time spent in idle state (P_i)—Speed $\leq 5 \text{ kmph}$ and acceleration -0.1 to 0.1 m/s^2

Table 2 shows the dominant driving parameters for the influence zone. The parameters are estimated based on the criteria mentioned in the previous section. Percentage time acceleration for Ambedkar circle varies from 43 to 49%, deceleration 40 to 47% with almost zero idle time. It is observed that maximum time is spent in acceleration and deceleration states (almost greater than 90%) by MTW. The results for motorcycle and car are similar to MTW as less idling period observed from the assessment

Table 2 Driving parameters for intersection influence zone





Cycles	% Acceleration (P_a)	% Deceleration (P_d)	% Idle (P_i)	% Cruise (P_c)	Time (s)
<i>MTW</i>					
1	49.59	42.15	0.00	8.26	36.3
2	48.86	41.48	0.00	9.66	17.6
3	45.92	43.54	0.00	10.54	29.4
4	43.54	46.86	0.55	9.04	54.2
5	48.96	40.37	0.00	10.67	43.1
6	46.08	47.28	0.00	6.62	33.2
<i>Motorcycle</i>					
1	49.85	44.00	0.00	6.15	32.5
2	18.95	22.51	55.92	2.62	95.5
3	44.80	47.98	0.00	7.22	34.6
4	45.43	44.69	0.00	9.88	40.5
5	39.17	47.45	6.85	6.53	62.8
6	45.22	44.96	0.00	9.82	38.7
7	44.61	46.62	0.00	8.77	39.9
<i>Car</i>					
1	48.64	43.67	1.24	6.45	40.3
2	45.56	44.44	0.00	10.00	27.0
3	38.89	48.15	0.00	12.96	27.0
4	50.56	40.08	0.00	9.36	26.7
5	23.27	24.88	47.39	4.46	105.3
6	39.91	41.44	14.07	4.58	91.7
7	47.46	45.52	0.00	7.02	41.3

of the parameters. For cars, overall it is observed that the idling period is high in a few driving cycles like 47 and 14%, which shows the influence of signal red interval time on the driving mode. It is observed that idling time for a few cycles is too high compared to their acceleration and deceleration time because of the influence of test vehicles under signal control at the time of data collection. Overall, it is observed that 6–10% of time is spent in cruise mode for the influence zone.

3.3 Microscopic Traffic Simulation Model for Influence Zone

The VISSIM model is created for the intersection considering the assessed upstream and downstream distances of the intersection influence zone. The purpose of this condition for network building is to generate the corresponding zone in the simulation network. Table 3 shows the region of intersections for influence zone, identified for base data and hypothesized for VISSIM network. The greater distance on the upstream side of the VISSIM network is added to demonstrate buffer distance to the vehicles while entering the network. From several trials of the simulations, the 100 m buffer distance is given at the upstream to obtain an effective influence zone in the VISSIM network and to demonstrate exact field traffic conditions. Buffer distance serves the exact vehicle platoon as it is observed in the actual field. The vehicle starts maintaining an average standstill distance after the buffer zone, once it is fed from the link end. The greater distance provided at the downstream side of the VISSIM network is for the purpose of the aesthetic animations of the vehicles in the network. Thus, the influence zone length for the downstream side of the intersection as 200 m for base data is considered as 300 m in the VISSIM network. Figure 6 shows the region of influence zone in the network of VISSIM models. The VISSIM network building begins with the tool of ‘Link’, which creates the road element consisting of the number of lanes and road type. The respective links are connected with the ‘Connectors’. The crossing area of the intersection is constructed through connections of links and connectors by specifying definite driving directions. The four approaches were built for intersections according to their actual geometry. The left turning, straight and right turning movements of vehicles are provided separately as input parameters. It is observed that the major traffic flow is observed for the straight

Table 3 Region of influence zone in base data and VISSIM model

Intersection	Region of influence zone (m)	Distance from intersection US DS 	Region of influence zone (m)	Distance from intersection US DS 
	Base data		VISSIM model	
Ambedkar Circle	500	300 m 200 m 	700	400 m 300 m 

US and DS Up Stream and Down Stream of intersection

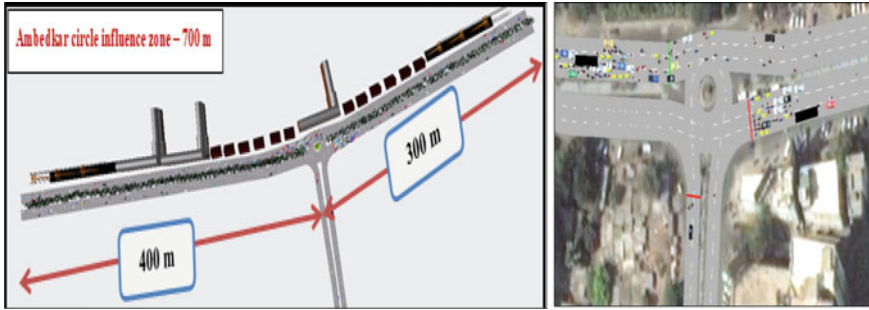


Fig. 6 Region of influence zone in VISSIM models

movement of the intersection along the major street. The minor street approaches consist of less traffic volume and varying road width.

3.4 Calibration and Validation of VISSIM Model

In most cases, the traffic volume and travel times are extensively used to calibrate the simulation models, rather than prevailing driving characteristics such as speed and acceleration. However, these driving behaviour parameters evaluate vehicle emissions to a great extent [9]. VISSIM will calibrate the driving performance associated with the network's driving conditions. The model calibration method refines the input parameters made in the VISSIM network to achieve exact traffic conditions [10]. To functionally simulate Indian heterogeneous traffic conditions, default driving parameters must be changed. The driver's behaviour characteristics of individual vehicles in the simulation model are regulated by operational calibration parameters in VISSIM. Desired speed, desired acceleration, lane change distance, look ahead distance, look back distance and standstill distance are the parameters calibrated in VISSIM [11].

The validation of the calibrated network is accomplished through a comparison of traffic conditions perceived in the field and simulation network [12]. In the present study, driving cycle parameters and speed trajectory of vehicles are evaluated for validation of the network. RMSE and MAE are statistical measures that can be used to compare modelled and observed flow. The Root Mean Square Error (RMSE) is a statistical error calculation criterion used to determine the relationship between real count data and model-predicted volume data [13]. The mean absolute error is also known as mean absolute deviation, which measures the accuracy of predicted value statistically. Table 4 shows modelled and observed driving parameters. P_i for the motorcycle shows significant variation in the observed and modelled data set, it shows the highest RMSE as 19.60 among all parameters. The remaining parameters show the RMSE less than 10 for MTW, motorcycle and car. It means the average difference between modelled and observed value is less than 10, which shows the significant match between values of observed and modelled data.

Table 4 Driving cycle parameters for observed and modelled data

Parameters	P _a (%)	P _d (%)	P _i (%)	P _c (%)
<i>MTW</i>				
Observed	47.16	43.61	0.09	9.13
Modelled	45.01	43.97	1.26	9.76
RMSE	8.28	8.81	1.56	5.78
MAE	5.25	5.23	0.87	3.97
<i>Motorcycle</i>				
Observed	41.15	42.60	08.97	7.28
Modelled	37.88	36.84	23.37	1.91
RMSE	6.30	8.91	19.60	6.07
MAE	4.12	7.00	14.77	4.71
<i>Car</i>				
Observed	42.04	41.17	08.96	7.83
Modelled	39.20	38.87	13.96	7.97
RMSE	5.50	5.71	10.02	6.34
MAE	3.68	4.64	6.53	5.03

RMSE Root Means Square Error, *MAE* Mean Absolute Error

The validation of the speed profiles of vehicles is presented graphically. It is attained by relating driving cycle profiles of the influence zone of real field data and simulated data. VISSIM offers individual vehicle's speed-time data with a precision of 0.05 s time interval. For each vehicle class, arbitrary eight-speed-time data is extracted from the VISSIM output. The extracted data is used to plot a graph of the driving cycle profile, and similar data is used to determine the driving parameters. The graph of the influence zone for the observed driving cycles and modelled driving cycles are compared visually. It is observed that the percentage time of the idle state is more in simulation results, whereas percentage time acceleration and deceleration are less than the observed data. VISSIM is based on the car following model in which the driving behaviour for different vehicle classes is given separately to run the model. Driving behaviour in the simulation network depends on the behaviour of the preceding vehicle when it approaches an intersection at low speed, so the corresponding deceleration, idle and acceleration states are observed in simulation profiles. It is also observed from the speed profiles that acceleration and deceleration slope is smooth in simulation compared to fluctuations in actual profiles. However, the rate of change of speed is identical in each time step of the simulation due to the analogous speed distribution of individual vehicle classes. VISSIM is not able to spawn the vehicles' speed as it is observed in the actual field, it shows the same speed distribution for specific vehicle classes. Because of this reason, it shows the smooth acceleration and deceleration slopes in the profiles of the driving cycle. Overall, it is observed that the graphical comparison of the driving cycle highlights the nature

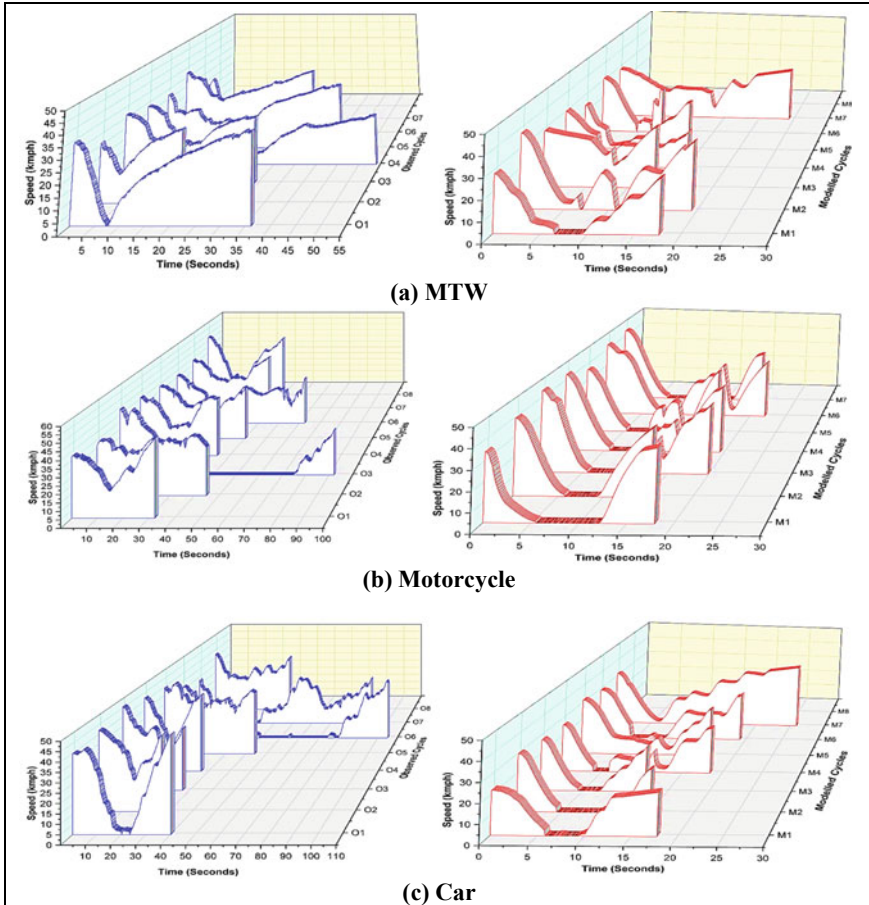


Fig. 7 Observed and modelled driving cycles

of the profile of the speed data of the vehicles. Figure 7 shows the observed and modelled driving cycles for MTW, motorcycle and car.

4 Conclusion

The distance of the influence zone for the upstream and downstream intersection sides is identical for all three modes of vehicles. The length of the influence zone extensively depends on the intersection control operations and traffic volume. The results of three dominating parameters of influence zone (deceleration, idle and acceleration) show that for MTW, 90–95% time spent for acceleration and deceleration states, whereas approximately 5–10% time spent on the idle state. For motorcycles and cars, the idling time is greater than acceleration and deceleration for selected

cycles, almost greater than 10%. The percentage acceleration, deceleration, idle and cruise states are significantly dependent on the signal cycle operations for signalized intersection. Also it depends on the influence of the vehicle under red interval time at the time of data collection. The geometric features of the road play a significant role in creating a vehicle's platoon. Driving parameters depend on these all aspects and the driver behaves accordingly in a traffic stream. So, the driving parameters' value is different for different vehicle classes. It does not depend on individual vehicle class. Driving characteristics of vehicles are observed to be varying significantly at different intersections, hence identification of the influence zone at the intersection is extremely important to quantify vehicular emissions exclusively because of the presence of intersections. The greater share of MTW, motorcycle and car in the study area are the focus for the exclusive analysis of speed profiles. The prime focus of the analysis is to recognize the exact stretch of the influence zone for three modes of vehicles associated with speed fluctuation in the vicinity of intersections.

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