Development of Candidate Driving Cycles for an Urban Arterial Corridor of Vadodara City

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Abstract

Road transport is the main contributor of emissions through vehicle exhaust. Vehicle exhaust emissions exclusively depend on vehicle characteristics, road geometry, traffic characteristics, atmospheric conditions, vehicles' age and driving behaviour. In the road network, intersections are crucial elements because of their regulation, traffic composition and geometric features. Generally, the driver has to decrease speed and sometimes stop for a long period of time while approaching the intersections, which cause a high concentration of emissions. It is a prior need to study the speed pattern of vehicles at intersections in the wake of fundamental for air quality analysis. To comprehend the driving characteristics of an individual vehicle and speed variation at the intersection, the driving cycle is an important concept being used from many years. Driving cycle is the speed-time profile of the vehicle in stipulated traffic condition. To represent the driving characteristics of an area or a city, the development of the driving cycle is an appropriate approach. It is the process of generating candidate driving cycles associated with vital driving parameters such as acceleration, deceleration, cruise and idle. Numbers of methods have been proposed for the development of the candidate driving cycles based on the purpose of the analysis. In the present study, micro-trip based driving cycle analysis approach is used for urban intersections of Vadodara city, India. Micro-trips are defined as speed profile of the vehicles from upstream to downstream of the intersection, it is the stretch at which succession driving states deceleration, idle and acceleration observed distinctly in the vicinity of intersections. To collect the speed data, the V-box (Velocity box) is embedded on the test vehicles of motorized three wheelers, motorcycle and car. The result shows that the percentage of time spent in acceleration-deceleration state for motorized three wheelers relatively 45% greater than motorcycle and car as 25%. The idling period is high for motorcycle and car ranges from 42-45%. Validation of candidate driving cycles is accomplished through the sum squared difference between data set.

*Keywords:*Driving cycle, micro-trip, acceleration, deceleration, Speed Acceleration Probability (SAP), Sum Square Difference (SSD)

1. Introduction

Transportation-related vehicle exhaust emissions become a serious risk to an urban area, affecting air quality and human health (Tsai et al., 2017, Knez et al., 2014, Adak et al., 2016). It is essential to implement air quality control strategy by policymaker to

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make a sustainable urban area (Arun et al., 2017). Traffic flow in urban intersections is described by lane changing and high level of maneuverability, a result of interactivity of fast and slow moving vehicles. Thus intersections are considered an instant source of traffic jam and zone of high air pollution concentration due to the varying speed of vehicles (Pandian et al., 2009). It is significant to study traffic characteristics of intersections to improve its capacity and thereby to reduce emissions. To seek speed fluctuation at urban intersections; the characteristics of the traffic, road and vehicles should be analyzed to produce effective prediction results which are worthwhile for implementing transport policies. To analyzethe speed pattern of vehicles, the driving cycle is an essential concept used comprehensively (Achour et al., 2016, Tsai et al., 2005). Driving cycles are a representation of the sequence speed-time profile of vehicles (Galgamuwa et al., 2015). Driving cycle is the concatenation of vehicle operating conditions; acceleration, deceleration, cruise and idle (Pathak et al., 2010, Tzirakis et al., 2006). Driving cycle analysis involves the construction of a representative cycle which describes driving characteristics of an area or a region (Tamsanya et al., 2006). Evaluation of driving cycles can be achieved by assessing driving parameters such as speed, acceleration, deceleration, cruise and idle time (Barlow et al., 2009). In the present study, micro-trip based driving cycle analysis approach is used for calculating driving parameters in the wake of more number of stops observed in the corridor (Dai et al., 2008, Han et al., 2012). The uniqueness of the methodology is that micro-trips are the stretch in the vicinity of intersection consisting driving states; deceleration, idle and acceleration. These driving parameters become intensive due to the influence of intersection on vehicle speed under heterogeneous traffic conditions. The base driving cycle is segregated into a number of micro-trips and further analysis can be achieved through analysis of speed based parameters (Gunther et al., 2017, Seedam et al., 2015). A candidate driving cycle is constructed by compiling and arranging micro-trips in series.The performance of speed acceleration frequency is employed to examine the validity of candidate cycles (Hung et al., 2007). The study area consisting of a series of five intersections located in close proximity and dealing mixed traffic conditions.

1.1 Objectives and literature

The main objective of this research is to construct candidate driving cycles based on micro-trip analysis approach considering three driving parameters; percentage time spent in acceleration (P_a), deceleration (P_d) and idle (P_i)state. K means clustering algorithm is used to bin micro-trips of analogous characteristics. Evaluation of candidate driving cycles is accomplished through analysis of speed-acceleration characteristics of driving parameters. Validation of candidate cycle is attained through the sum of the squared difference between speed- acceleration data of candidate cycles and base cycles.

The real world driving cycle profiles of the three modes of vehicles is considered as base cycles. It is observed from the speed profile near the intersection that speed reduces far from the upstream side of the intersections and almost zero at intersections, and while leaving the intersection it increases gradually. Many researchers have carried out a study on driving cycle development from micro-trip analysis technique. In which the micro-trip is the small section of the driving cycle from idling to idling state, whereas in the present study the micro-trip is the stretch of deceleration to the acceleration of the driving cycle at intersections. The study concentrates the stretch of the intersections includes these actions of driving in sequence.

Kamble et al. (2009) developed a Pune driving cycle based on micro trip analysis approach. Driving parameters; acceleration, deceleration cruise, idle and average speed of vehicles are evaluated. The developed cycle is compared with the existing Indian Driving Cycle (IDC). Tamsanya et al. (2009) explained the procedure for generating the driving cycle from real driving data of Bangkok traffic. Parameters of the new driving cycle are compared with real-world measured data. The real world traffic data is obtained by speed time data logger equipped in a test car. Seers et al. (2015) have proposed a methodology for the development of specific cycles for the city of Salaberry-de-Valleyfield (SdV)based on experimental data. Generated cycles are implemented in standard dynamometer measurements. Driving characteristics in the aggressiveness of proposed cycles produce higher fuel consumption and pollutant emissions than conventional driving cycles. Galgamuwa et al. (2015) evaluated various methods used for the development of driving cycles under various conditions. The purpose of the study is to develop indicative driving cycles for given locations.

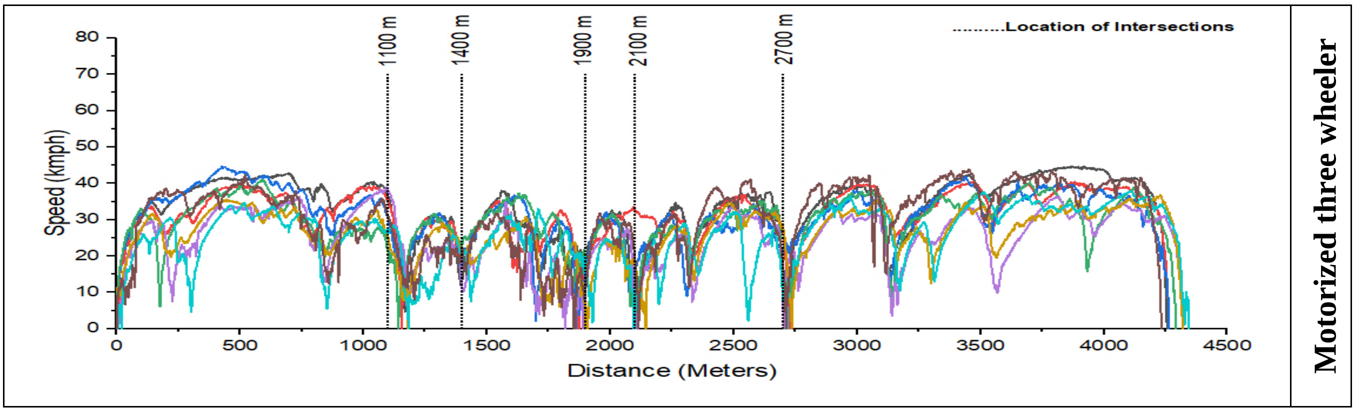
2. Field study and data collection

Study on speed characteristics at intersections is one of the most effective measures to enhance the road network capacity, to relieve traffic congestion and thereby to reduce speed based emissions. Closely spaced signalized intersections on urban arterials result in unreasonable stops, unnecessary delay, more fuel consumption and high emissions (Stover, 2007). Long and uniform spacing of major signalized intersections enables to provide effective traffic flow at the road network and to achieve the desired speed of vehicles. In lieu of this problem, the study has been carried out for an arterial corridor (six-lane divided dual carriageway) in the metropolitan Indian city of Vadodara in the state of Gujarat. The corridor is consisting of four signalized intersections and one rotary intersection. V-box was embedded on vehicles to capture speed trajectory of individual vehicles. V- box is able to collect data through a GPS attached system related tothe speed accuracy of the vehicle at every 0.1 seconds. Figure 1 (a) and (b) showsa distance of intersections in corridor and instrument V-box respectively. The speed survey has been collected for mainly three modes of the vehicles; motorized three wheeler, motorcycle and car in the morning peak hour period of weekdays. It is observed that almost 95% of vehicle composition comprises these three modes of vehicles in the study area, so the speed characteristics can be effectively analyzed for the entire corridor. The view of intersections is shown in Figure 2. The intersection types and traffic volume in vehicles per hour are shown in Table 1. Driving cycle profiles of the motorized three wheelers, motorcycle and car are shown in Figure 3. It is observed that the speed of vehicles reduces remarkably while test vehicles approaching the intersections.

(a) (b)

Figure 1: (a) Distance of intersections (b) V-box.

Figure 2: Intersections view.



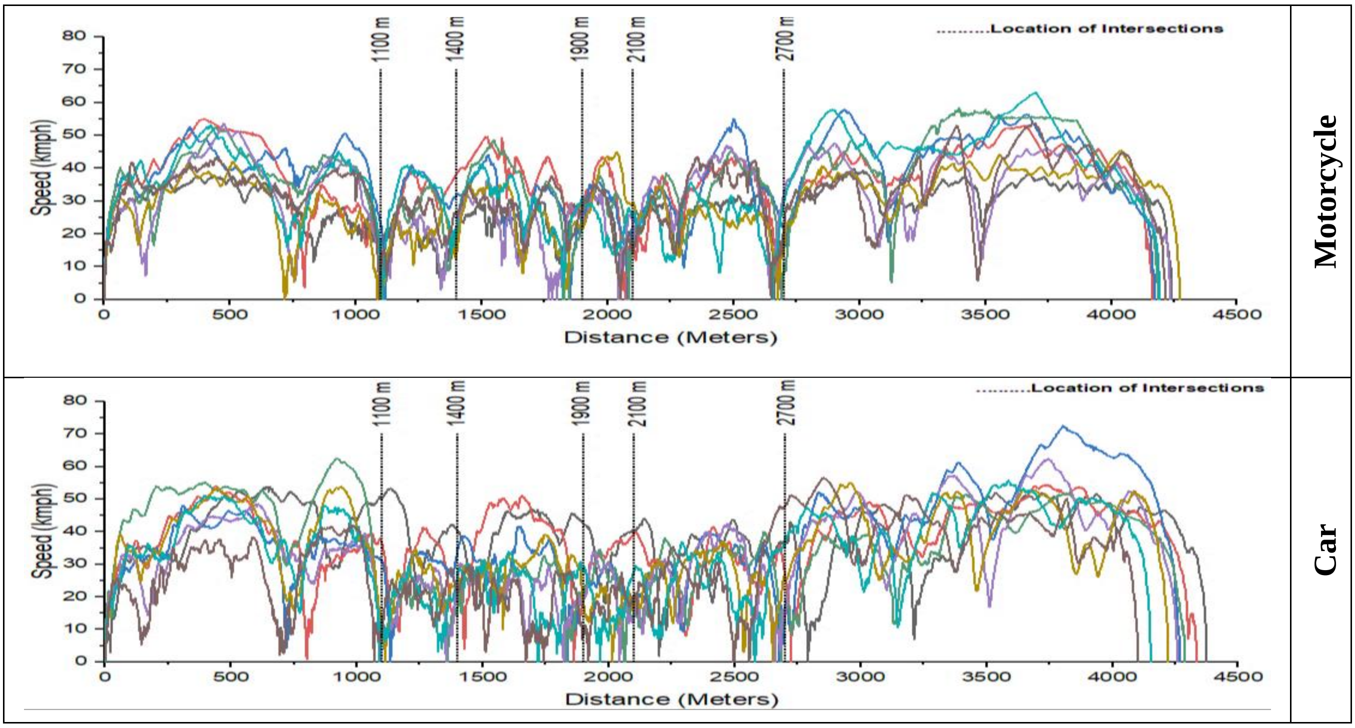


Figure 3: Driving cycle profiles.

Table 1: Intersection characteristics.

Intersections	*Distance (m)*	*Type*	*Traffic volume (v/h)*
Genda Circle (GC)	0	Four-legged Rotary	-
Ambedkar Circle (SI-1)	1100	Three-legged Signalised	6639
Chakli Circle (RI)	1400	Four-legged Rotary	8865
Malhar Circle (SI-2)	1900	Four-legged Signalised	7765
Havmor Circle (SI-3)	2100	Four-legged Signalised	8659
VasnaCicle (SI-4)	2700	Four-legged Signalised	8214
Akshar Chowk (AC)	4300	Three-legged Rotary	-

Table 2: Vehicle compositions at intersections.

Sr. No.	***Vehicle class***	***Composition (%)***				
		SI-1	***RI***	***SI-2***	***SI-3***	***SI-4***
1	Cycle	1.60	1.17	4.89	04.20	2.02
2	Motorcycle	59.51	62.24	66.62	63.30	63.53
3	MTW	14.84	11.99	8.11	08.72	10.71
4	Car	22.40	22.57	18.56	21.67	21.33
5	LCV (Light Commercial Vehicle)	0.83	1.80	1.33	1.80	1.87
6	Minibus	0.03	0.03	0.00	00.02	0.00
7	Bus	0.62	0.02	0.05	00.05	0.10
8	HGV (Heavy Goods Vehicle)	0.18	0.16	0.44	00.24	0.44

Table 2 shows vehicle compositions of individual intersections in the morning peak hour period from 10:00 am to 11:00 am on a week day. It is observed that nearly 60-65% of the vehicles plying on the corridor are motorcycles, whereas 10-15% MTW and approximately 22% car; contributes 92-95% of vehicles share. The study focuses on the analysis of the speed characteristics of the major mode of travel in the corridor. The percentage share of heavy vehicles and buses is less than 1%, whereas the cycle composition varies from 1.6% to 4.8% and LCV shares less than 2%.

3. Data Assessment

Driving cycle development is the important process of evaluating the speed of vehicles concerning time and distance. The speed profiles of the vehicles in real traffic condition don't assist the speed characteristics of the entire area. They simply provide speed data of vehicles which are purposely plying in the study area in existing traffic conditions. It is necessary to generate typical speed profiles of vehicles in various traffic conditions, which is representing prevailing speed characteristics of a particular area or a city. This promotes the step to build the driving cycle of various vehicles from the actual speed data, which presents complete speed characteristics of an area. There are mainly three steps associated in driving cycle construction; selection of the route, data collection and driving cycle construction. Route selection involves seeking an indicative route which expresses the varying road-traffic conditions, so the generated cycles can be further held for representing speed characteristics of the city. In data collection, the speed of test vehicles was recorded precisely by V-box instrument with the precision of 0.1 seconds. The cycle construction steps entail data separation into micro-trips, evaluation of parameters of micro-trips and developing candidate driving cycles by compiling representative micro-trips. The micro-trips are segregated from the base driving cycles and their influential driving parameters are evaluated. Set of micro-trips are formed using K-means clustering based on their equivalency in driving characteristics. Micro trips possess identical characteristics are binned in a single group. Three driving parameters are evaluated to describe the clusters of micro-trips; deceleration, idle and acceleration. Numbers of clusters were selected to perceive all possibilities for obtaining optimum cluster number, which would able to construct candidate driving cycle with less error. The representative micro trip is selected from each cluster which carries the least cluster distance within the group (Fotouhi et al., 2013). All representative micro-trips are separated and arranged in succession to construct representative candidate cycles. The arrangement of micro-trips assembles one candidate cycle and the process is repeated to generate the number of candidate cycles. Candidate driving cycles are evaluated based on the SSD performance measures. The candidate cycle construction process is shown in Figure 4.

3.1 Micro trip generation

The upstream and downstream areas of intersection are called functional areas of intersections (Rice, 2010).These functional areas help in identifying the actual zone of influence of the intersection in terms of vehicular deceleration and acceleration activities. So, these areas are exclusively considered for evaluating vehicular emissions occurring because of the role of intersections. The length of the upstream area of an intersection varies concerning deceleration distance while driver maneuvers to halt state. The upstream area is greatly dependent on whether the traffic in through lane comes to a halting state at the intersection or not. Road traffic characteristics of the study area involve a sequence of intersections close to each other and long signal cycle time.It causes traffic congestion and encourages rapid acceleration, deceleration and greater idling time around signalized intersections. Drivers maintain desired speed during a green interval at the intersection, whereas in a red interval, drivers are forced to decelerate the vehicle and sometimes halt for a longer duration. Speed fluctuations near intersectionsstart with deceleration mode, followed by idle and acceleration state. When vehicles proceedin the influence ofthe intersection zone, the driver has to compulsorily maintain speed according to the preceding vehicle while following it.

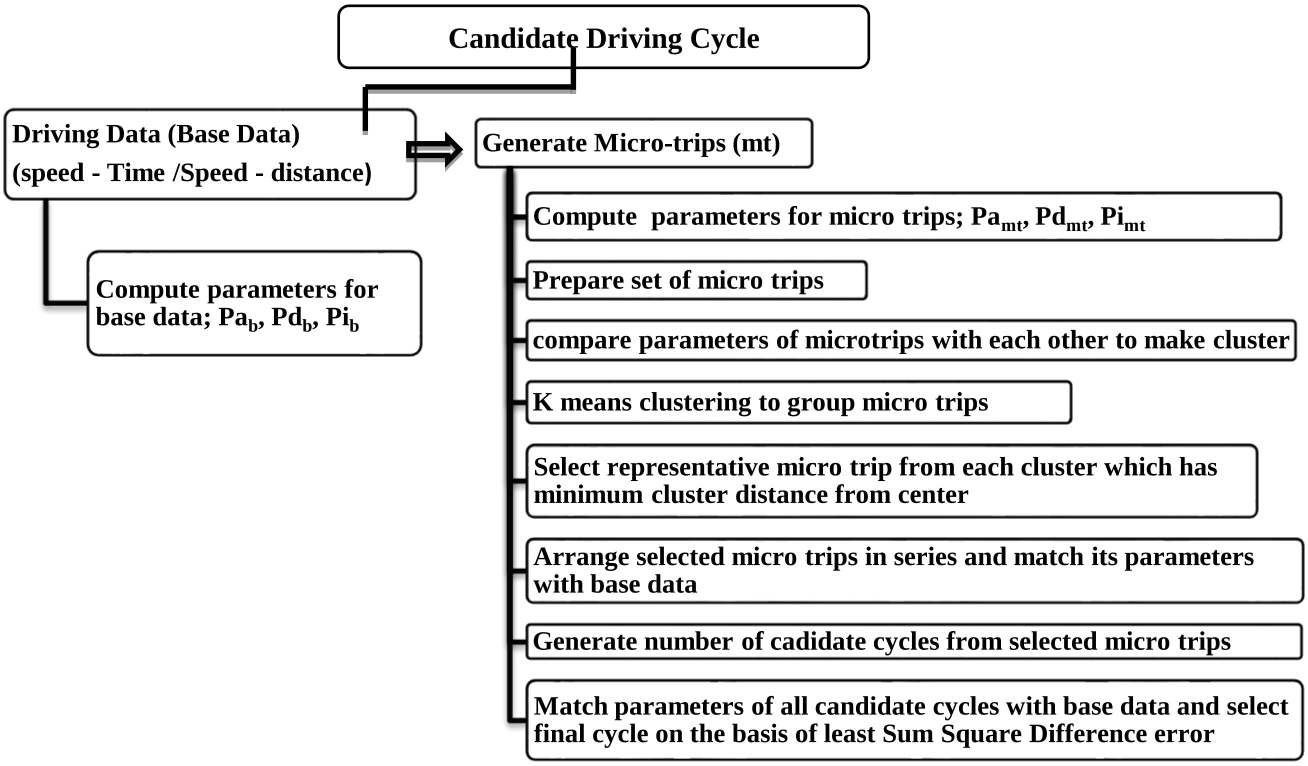


Figure4: Candidate driving cycle construction process.

In the study, an attempt was made to identify the influence zone of intersections with greater speed fluctuation by comparing distance-time and speed-time trajectory of vehicles on a similar time scale. The influence zone for a single driving cycle is considered as one micro-trip associated with driving activities at the intersection.The characteristics of micro-trips depend on the traffic conditions, time of data collection and vehicle composition. Three parameters of the driving cycle are calculated for base trips and micro-trips; P_a, P_d and P_i (Pouresmaeili et al., 2018). A stretch of micro trip is marked fromthe corresponding speed-time trajectory and distance-time profile of vehicles in a similar time scale is shown in Figure 5 (Chauhan et al., 2018). Time properties of driving states are computed for base data and micro-trips based on the following criteria (Nesamani et al., 2011, Pathak et al., 2016, Arun et al., 2017):

1. Acceleration P_a, $a(t) > 0.1$ m/s^2
2. Deceleration P_d,$a(t) < -0.1$ m/s^2

3. Idle P_i, $v(t) < 5$ kmph and -0.1 m/s$^2 \geq$ $a(t) \leq 0.1$ m/s^2

Driving parameters of micro-tripsfor three modes of vehicles are shown in Table 3. Percentage time of acceleration for SI-1 is found approximately 43%, Deceleration time 44% and idle time less than 1% for motorized three wheelers. For the motorcycle, it is observed that percentage acceleration and deceleration time is distinctly less, varies in a wide range of 20% to 57% with greater idling time. For car mode, acceleration time is comparatively lower than deceleration time. Idling time varies from 0 to 46%. Less idling time indicates that the vehicle was not discerned under influence of intersection control at the time of data collection.

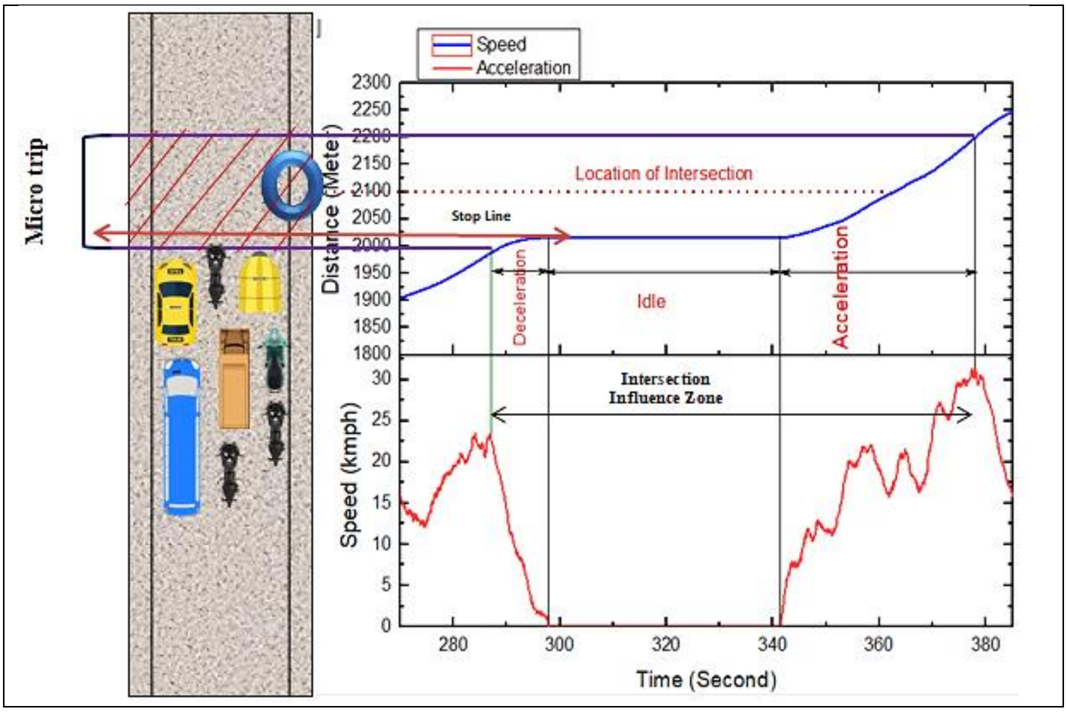


Figure 5: Micro trip from base data.

Table 3: Driving Parameters of micro-trips for SI-1.

Micro trips	*Motorized three wheeler*			*Motorcycle*			*Car*		
	A (%)	*D (%)*	*I (%)*	*A (%)*	*D (%)*	*I (%)*	*A (%)*	*D (%)*	*I (%)*
1	47.89	45.66	00.25	44.64	48.72	00.00	34.44	57.61	00.00
2	45.73	44.82	00.31	23.02	21.90	51.84	47.73	49.54	00.00
3	44.51	45.38	00.00	14.85	19.07	63.19	48.13	46.25	00.00
4	32.58	31.13	30.16	39.87	52.73	00.00	39.96	53.63	00.64
5	42.19	51.51	00.55	34.54	57.10	00.00	28.54	37.64	29.64
6	46.36	43.16	00.36	32.68	32.68	30.71	26.66	29.51	40.00
7	47.57	44.41	00.69	20.03	22.36	55.28	23.15	26.68	46.29
8	41.11	52.50	00.00	37.44	44.08	12.56	24.16	30.03	41.44

A-Acceleration, D-Deceleration, I-Idle

3.2 Micro-trips clustering

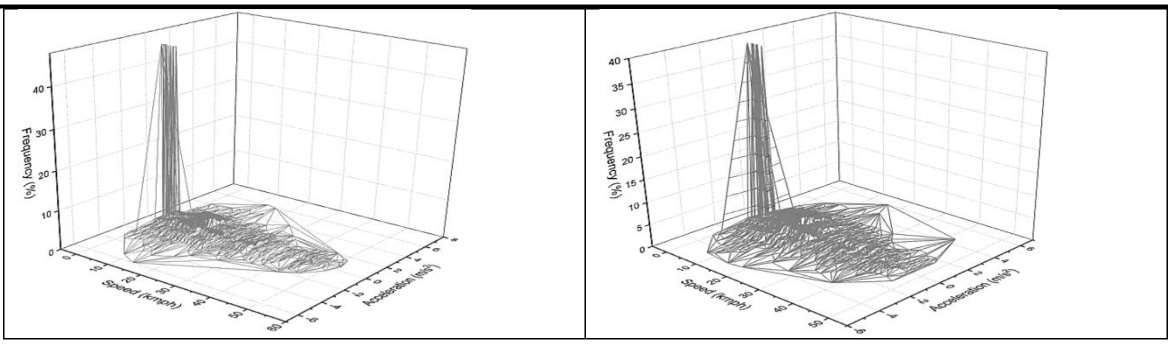
Clustering is an appropriate approach to the concise large number of micro-trips into a definite group. K means clustering is one of the simplest and popular algorithms used for grouping enormous data set. It recognizes k number of centroids and assigns data to the nearest cluster. Clustering of micro-trips is the process of partitioning a given data set in k groups based on similarity in driving parameters (Fotouhi et al., 2013, Landau, et al., 2015). In the present study, micro-trips are clustered into k number of groups subject to defined driving parameters. Micro trips have similar characteristics are grouped in a single cluster. A representative micro trip from each cluster is selected based on its distance from the cluster center, possesses least cluster distance (Gupta et al., 2011). Candidate driving cycle is generated by chaining of representative micro-trips from an individual cluster. In the present analysis, K means clustering is carried out bySPSS (Statistical Package for the Social Sciences) software. Micro trips parameters; P_{ma}, P_{md} and P_{mi} are calculated and compared with each other to frame number of groups. Micro trips possess identical characteristics are binned in a single group. Three driving parameters have attributed to describe a cluster of micro-trips. Numbers of clusters were selected to perceive all possibilities for obtaining optimum cluster group, which would able to construct candidate driving cycle with less error. The representative micro trip is selected from each group which carries the least cluster distance within a group (Gupta et al., 2011, Fotouhi et al., 2013). All representative micro-trips are separated and arranged in series to construct candidate cycles. The arrangement of micro-trips assembles one candidate cycle, represents speed characteristics of the study area. The arrangement of micro-trips is repeated to generate a number of candidate cycles. Candidate driving cycles are evaluated on the basis of sum squared difference error between base cycles and candidate cycles.

3.3 Speed Acceleration Probability (SAP) matrix

It was known that the overall percentage value of the driving parameters does not contribute prominent observation of their distribution in vital range. To understand broadly, the occurrence of speed and acceleration was studied over the driving time (Berta et al., 1998). The frequency of speed and acceleration is considered as distinctive traffic characteristics of a particular vehicle for a given route. It is the most common considerable analysis to check the reliability of the driving cycle to represent it for the specific application. The Speed- Acceleration Probability (SAP) is the appropriate approach for distributing the frequency of the occurrence of driving parameters; deceleration, acceleration, idle and cruise (Kamble et al., 2009). The matrix is very important for comparing the parameters of generated candidate cycles in definite speed and acceleration group. For comparison of the base and candidate cycles activity, the matrix is normalized (Lipar et al., 2016). Percentage of time spent on parameters is estimated by normalizing values ofthe base matrix. It is difficult to handle enormous speed data of base cycles manually for engendering SAP matrix. Looking to this problem, computer code is developed in C# for accessible interpretation of data. Table 4 shows the speed acceleration probability matrix for base data for motorcycle mode. A three-dimensional diagram is displayed in Figure 7, which shows the frequency of the driving cycle for the base cycle and candidate cycle of the motorcycle.

Table 4: SAP matrix for base data for motorcycle.

Acceleration(m/s²)→ *Speed (kmph)↓*	*-4 to -3*	*-3 to -2*	*-2 to -1*	*-1 to -0.1*	*-0.1 to 0.1*	*0.1 to 1*	*1 to 2*	*2 to 3*	*3 to 4*	*4 to 5*	*5 to 6*	*Total*
0 - 5	2	7	16	25	1319	17	10	13	0	0	0	1409
5 - 10	2	3	25	37	5	23	14	5	4	0	0	118
10 - 15	2	11	36	60	23	74	30	8	1	0	1	246
15 - 20	1	8	53	123	19	107	56	8	1	0	1	377
20 - 25	1	10	39	70	15	50	32	11	2	2	1	233
25 - 30	1	8	40	106	17	106	42	8	1	1	0	330
30 - 35	0	3	15	32	14	50	24	5	0	0	0	143
35 - 40	0	0	5	34	7	51	19	2	0	0	0	118
40 - 45	0	0	0	9	2	17	9	1	0	0	0	38
45 - 50	0	1	1	3	1	13	7	0	0	0	0	26
50 - 55	0	0	0	3	3	18	4	0	0	0	0	28
55 - 60	0	0	0	6	0	16	1	0	0	0	0	23
Total	9	51	230	508	1425	542	248	61	9	3	3	3089



(a) (b)

Figure 7:SAP plot for motorcycle mode (a) Base cycle (b) Candidate cycle.

3.4 Validation of candidate cycles

Validation is the process of checking the acceptability of developed candidate cycles. The candidate driving cycles are validated by the Sum of Squared Difference (SSD) between two cycles. SSD is the difference in the frequency of individual speed acceleration data value. Equation 1 shows the difference in individual speed and acceleration class of observed data and modelled data (Pokharel et al, 2013).

$$\mathrm{SSD} = \sum_{i=1}^{Ns}\sum_{j=1}^{Na}(P_{ij} - Q_{ij})^2 \qquad (1)$$

Where Ns and Na are speed and acceleration categories respectively, P_{ij} is the ijth entry of the SAP of the candidate driving cycle, and Q_{ij} is the ijth entry of the SAP of the base driving cycles. The candidate cycle owning to least SSD value is selected as a representative cycle for the study area. SAP matrix for the base cycle and candidate cycle is normalized to obtain SSD value of two observations. The base cycle normalized SAP matrix for motorcycle mode is shown in Table 5. Percentage time spent for acceleration, deceleration and idle state can be easily calculated by normalized matrix. Individual speed and acceleration frequency of candidate cycle 2 for the motorcycle is shown in Table 6 based on the results of Table 8. The squared difference of two matrices in typical speed acceleration range is highlighted in Table 7.

Table 5: Normalized SAP matrix of base cycle for motorcycle mode.

Acceleration (m/s^2) → *Speed (kmph) ↓*	*-4 to -3*	*-3 to -2*	*-2 to -1*	*-1 to -0.1*	*-0.1 to 0.1*	*0.1 to 1*	*1 to 2*	*2 to 3*	*3 to 4*	*4 to 5*	*5 to 6*	*Total*
0 - 5	0.065	0.227	0.518	0.809	42.70	0.550	0.324	0.421	0.000	0.000	0.000	45.613
5 - 10	0.065	0.097	0.809	1.198	0.162	0.745	0.453	0.162	0.129	0.000	0.000	03.820
10 - 15	0.065	0.356	1.165	1.942	0.745	2.396	0.971	0.259	0.032	0.000	0.032	07.964
15 - 20	0.032	0.259	1.716	3.982	0.615	3.464	1.813	0.259	0.032	0.000	0.032	12.205
20 - 25	0.032	0.324	1.263	2.266	0.486	1.619	1.036	0.356	0.065	0.065	0.032	07.543
25 - 30	0.032	0.259	1.295	3.432	0.550	3.432	1.360	0.259	0.032	0.032	0.000	10.683
30 - 35	0.000	0.097	0.486	1.036	0.453	1.619	0.777	0.162	0.000	0.000	0.000	04.629
35 - 40	0.000	0.000	0.162	1.101	0.227	1.651	0.615	0.065	0.000	0.000	0.000	03.820
40 - 45	0.000	0.000	0.000	0.291	0.065	0.550	0.291	0.032	0.000	0.000	0.000	01.230
45 - 50	0.000	0.032	0.032	0.097	0.032	0.421	0.227	0.000	0.000	0.000	0.000	00.842
50 - 55	0.000	0.000	0.000	0.097	0.097	0.583	0.129	0.000	0.000	0.000	0.000	00.906
55 - 60	0.000	0.000	0.000	0.194	0.000	0.518	0.032	0.000	0.000	0.000	0.000	00.745
Total	0.291	1.651	7.446	16.445	46.131	17.546	8.028	1.975	0.291	0.097	0.096	100

Table 6: Normalized SAP matrix of candidate cycle 2 for motorcycle mode.

Acceleration (m/s^2) → *Speed (kmph) ↓*	*-5 to -4*	*-4 to -3*	*-3 to -2*	*-2 to -1*	*-1 to -0.1*	*-0.1 to 0.1*	*0.1 to 1*	*1 to 2*	*2 to 3*	*3 to 4*	*5 to 6*	*Total*
0 - 5	0.025	0.100	0.400	0.849	1.398	42.272	1.298	0.799	0.400	0.100	0.000	47.640
5 - 10	0.000	0.150	0.200	1.398	2.921	0.549	2.172	1.373	0.350	0.150	0.000	09.263
10 - 15	0.000	0.050	0.474	1.648	2.247	0.599	2.147	1.448	0.325	0.050	0.025	09.014
15 - 20	0.000	0.025	0.175	1.523	3.571	0.749	3.521	1.448	0.325	0.025	0.025	11.386
20 - 25	0.000	0.025	0.200	1.323	2.597	0.699	2.572	1.423	0.275	0.050	0.000	09.164
25 - 30	0.000	0.050	0.250	1.124	2.946	0.849	2.946	1.199	0.250	0.000	0.000	09.613
30 - 35	0.000	0.000	0.050	0.300	0.649	0.300	0.824	0.350	0.100	0.000	0.000	02.572
35 - 40	0.000	0.000	0.000	0.050	0.350	0.075	0.549	0.125	0.025	0.000	0.000	01.174
40 - 45	0.000	0.000	0.000	0.000	0.050	0.025	0.100	0.000	0.000	0.000	0.000	00.175
Total	0.025	0.4	1.748	8.215	16.729	46.117	16.13	8.165	2.047	0.375	0.050	100

Table 7: SSD for base cycle and candidate cycle for motorcycle mode.

Acceleration (m/s^2) → *Speed (kmph) ↓*	*-5 to -4*	*-4 to -3*	*-3 to -2*	*-2 to -1*	*-1 to -0.1*	*-0.1 to 0.1*	*0.1 to 1*	*1 to 2*	*2 to 3*	*3 to 4*	*4 to 5*	*5 to 6*	*Total*
0 - 5	0.001	0.001	0.030	0.110	0.347	0.183	0.560	0.226	0.000	0.010	0.000	0.000	1.467
5 - 10	0.000	0.007	0.011	0.347	2.969	0.150	2.036	0.846	0.035	0.000	0.000	0.000	6.402
10 - 15	0.000	0.000	0.014	0.233	0.093	0.021	0.062	0.228	0.004	0.000	0.000	0.000	0.656
15 - 20	0.000	0.000	0.007	0.037	0.169	0.018	0.003	0.133	0.004	0.000	0.000	0.000	0.372
20 – 25	0.000	0.000	0.015	0.004	0.110	0.045	0.908	0.150	0.007	0.000	0.004	0.001	1.244
25 – 30	0.000	0.000	0.000	0.029	0.236	0.089	0.236	0.026	0.000	0.001	0.001	0.000	0.619
30 – 35	0.000	0.000	0.002	0.035	0.150	0.023	0.632	0.182	0.004	0.000	0.000	0.000	1.028
35 – 40	0.000	0.000	0.000	0.013	0.564	0.023	1.214	0.240	0.002	0.000	0.000	0.000	2.056
40 – 45	0.000	0.000	0.000	0.000	0.058	0.002	0.203	0.085	0.001	0.000	0.000	0.000	0.348
45 – 50	0.000	0.000	0.001	0.001	0.009	0.001	0.177	0.052	0.000	0.000	0.000	0.000	0.241
50 – 55	0.000	0.000	0.000	0.000	0.009	0.009	0.340	0.017	0.000	0.000	0.000	0.000	0.375
55 – 60	0.000	0.000	0.000	0.000	0.038	0.000	0.268	0.001	0.000	0.000	0.000	0.000	0.307
Total	0.001	0.009	0.080	0.808	4.752	0.566	6.640	2.185	0.058	0.012	0.005	0.001	15.11

4. Results and Discussion

The candidate cycle parameters are compared with the base cycle in order to check their closeness. It is observed that parameters of candidate cycles almost match with the parameters of the base cycle indicating that the driving cycle precisely represents the driving characteristics of the study area. Driving parameters of the base cycle and candidate cycles for motorized three wheeler, motorcycle and car are highlighted in Table 8. Five candidate cycles have been generated for motorized three wheeler and motorcycle, whereas four candidate cycles are generated for the car mode. It is observed that candidate cycle 1 possesses the lowest SSD value as 31.2 among generated cycles for motorized three wheeler mode. Driving parameters of adopted candidate cycle-1 are; acceleration 47.28%, deceleration 44.91% and cruise 0.65%. For the motorcycle, candidate cycle-2 has the lowest SSD value 15.11, considered as a representative cycle because of its equivalency to base data. It is seen that time spent on acceleration and deceleration state is 26-27% and 42% of the idling period. In the car, cycle 1 shows nearly 28% of acceleration-deceleration and 39.20% of the idling period, reveals SSD value 44.65.

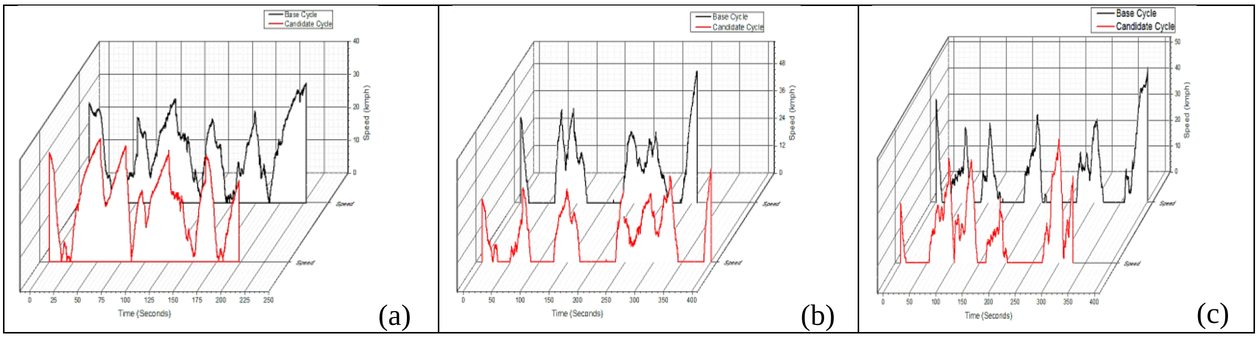


Figure 8:Base cycle and Candidate cycle profile for (a)Motorized three wheeler, (b)Motorcycle and (c) Car.

In mode wise comparison of results, it is found that motorcycle and car have more idling period than motorized three wheeler. Variation in vehicles' idling time depends on the time of data collection, queue formation, signal control system, road geometry, vehicle composition, etc. The speed profile of the base cycle and final candidate cycle are plotted for three modes are shown in Figure 8.

Table 8: Parameters of base cycle and candidate cycles.

Parameters	*%Acceleration*	*%Deceleration*	*% Idle*	*Trip length(m)*	*SSD*
		Motorized three wheeler			
Base Cycle	46.48	45.21	1.23	1035.16	-
Candidate Cycle - 1	**47.28**	**44.91**	**0.65**	**1021.57**	**31.20**
Candidate Cycle - 2	46.78	45.27	1.10	1028.09	31.70
Candidate Cycle - 3	44.32	47.38	1.04	804.29	35.05
Candidate Cycle - 4	47.16	44.96	0.59	782.17	83.68
Candidate Cycle - 5	45.15	46.87	0.51	831.24	93.89
		Motorcycle			
Base Cycle	28.03	25.83	42.70	1096.58	-
Candidate Cycle - 1	26.25	26.80	43.47	1063.35	22.09
Candidate Cycle - 2	**26.77**	**27.12**	**42.27**	**1106.41**	**15.11**
Candidate Cycle - 3	28.30	29.86	37.80	1080.95	41.54
Candidate Cycle - 4	28.60	31.39	35.39	1197.42	16.91

Candidate Cycle - 5	32.29	33.95	29.17	1284.84	19.75
		Car			
Base Cycle	25.82	25.38	45.46	1011.68	-
Candidate Cycle - 1	**28.60**	**28.70**	**39.20**	**0968.36**	**44.65**
Candidate Cycle - 2	30.52	28.66	36.95	1002.00	89.80
Candidate Cycle - 3	28.66	28.97	38.68	0928.83	53.67
Candidate Cycle - 4	25.77	31.09	39.18	1150.58	98.43

5. Conclusion

Driving cycle analysis is very important for developing the candidate driving cycle to present real traffic characteristics of an area. Accurate analysis of the driving cycle is essential because its further analysis is associated with precise emission estimation. In the present study, an attempt has been made to develop candidate driving cycles for three modes of vehicles for the urban arterial corridor. Micro trip based driving cycle analysis approach is used for examining driving parameters. The intersection influence area is considered a micro trip for the development of the candidate cycles. The validation of candidate cycles is accomplished through a performance measure SSD. The candidate cycle with the lowest error is selected as the final cycle and representing real traffic characteristics. It is observed from the results that in motorised three wheeler mode the speed pattern is almost similar for all cycles,comprises less idling period than motorcycle and car. It is found that idling period for motorcycle and car is higher than the acceleration and deceleration because of intersection control and queue formatted in a peak hour period. The speed acceleration probability matrix provides the frequency in individual speed and acceleration group explains detailed characteristics of speed. Parameters of candidate cycles depend on the method of analysis and characteristics of the actual speed data collected on the field.

The main findings of the study are:

1. For motorized three wheelers, 45-46% of time spent in acceleration and deceleration state for the base cycle and candidate cycles. The idling time at intersections is extremely low as less than 1%.
2. For motorcycle and car, the percentage of time spent on acceleration and deceleration varies from 25-28%, whereas greater idling time is 40-45%.

It is observed that when motorized three wheeler approaches the intersection at the time of data collection, it is the time of red phase completion and immediately green phase starts, which causes less idling state. When car and motorcycle approach intersections, detecting with red signal phase and stop for a long time cause more idling period.

The study is limited to three modes of vehicles. However, heavy vehicles are not considered in the analysis. It was observed that percentage share of heavy vehicles is less than 0.5%, considered as insignificant effect on the speed of vehicles while approaching the intersection due to low traffic composition in peak hour period.The high acceleration rate of vehicles significantly influences exhaust emission, which has been found after immediate deceleration and idle state. So the focus of the study is related to deriving three driving parameters, the cruise period of the cycle is not considered in the evaluation of the micro-trip. The final candidate cycle is reflected as representative of the speed pattern of the study area for particular mode and useful for further testing on chassis dynamometer for emission estimation.

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