Performance Evaluation of Urban Roadway Links Using V-Box

G. Yadav and A. Dhamaniya

Abstract Present study attempts to evaluate the operational efficiency of urban roadway links using V-Box. An urban arterial of 5.8 km length in Surat city of Gujarat is selected and divided into six links based on the number of intersections in the entire facility. All links are identical in geometry (six-lane divided) with different land use patterns. In order to evaluate the operational efficiency of these links, the number of runs of different categories of vehicles including motorized two-wheelers (2W), auto-rickshaw (3W), big car and small car (4W) and heavy vehicle (bus) has been taken at different time periods. A number of 30 runs of each vehicle category were taken on the entire facility for peak hours and non-peak hours. The collected data has been analysed for spatial and temporal variation in speed for different vehicle categories. The spatial variation has been checked by analysing the inter-segmental variation of speed. Also, within each segment, the variation of speed for different category of vehicles for peak and non-peak hours has been studied. Further, cumulative speed plots have been plotted to check the variability of speed for different segments for different vehicle categories. Furthermore, the excess speed over posted speed limit for different mid-block sections has also been checked.

Keywords V-Box · Temporal variation · Spatial variation

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1 Introduction

In a developing country like India, the traffic in urban streets is seeing a boost which affects the quality or the level of facility being provided by the road. Primary objective of this study is to carry out the performance evaluation of the urban roadway links using V-Box survey. This study aims to cover different aspects of traffic including average speed of different vehicles, travel time, controlled and uncontrolled delays, congestion factors and spatial and temporal variation of speed for the sections using V-Box analysis and checking its effectiveness in data collection and analysis. Variation in speed of vehicles on different mid-block segments of the same road is also an important aspect of analysing the performance of the roadway. How speed of stream or the speed of different vehicle categories changes on the same stretch with for different time periods is also needed to be determined for a given segment. This is known as spatial variation of speed. The level of service (LOS) term has been coined by the Highway Capacity Manual (HCM) which represents the level or standard of facility a user can derive from a road under various functional characteristics and traffic volumes. The term level of service is defined as a qualitative measure which describes the operational conditions within traffic stream, and their experience by motorists and travellers. This study checks this effect on six different mid-block sections of Gaurav Path in Surat city. In urban areas, with change in land use pattern along the roadway, the level of service changes. It leads to variation in travel time, average speed, delays and other parameters. The factor 'land use' has not been effectively considered for the determination of LOS till date. Hence, this study attempts to carry out the LOS determination with land use as a measure of effectiveness. The study shall aim to find the existing level of service on the selected road section and determine the present traffic conditions, so as to state if the present conditions fullfill the present demand or any measures are to be taken to overcome the problem eventually to be faced in the future. The outcomes of the study will be helpful for the analysis of the roads sharing similar geometric characteristics, land use and traffic conditions (composition, control parameters). Below curve shows the variation of speed with volume (Fig. 1).

2 Literature Review

In past years, many researchers have tried to assess level of service on the basis of different parameters. Maitra et al. (1999) have presented a unified methodology for the quantification of congestion at urban mid-block sections, relating the level of congestion to the casual influences of traffic movement by modelling, and demonstrate the potential use of modelled congestion as a measure of effectiveness for obtaining the LOS. However, the scope of this paper is restricted to the application
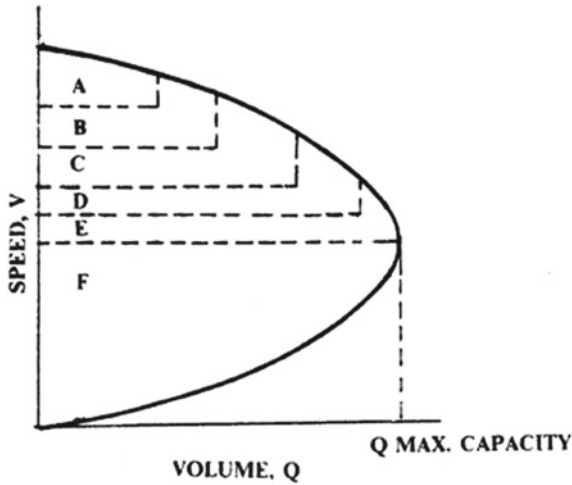
Fig. 1 Speed–volume curve showing level of service (IRC 106-1990: Guidelines For Capacity of Urban Roads in Plain Areas)

of the model on roadway condition in terms of traffic lanes only. Marwah and Singh (2000) has developed a traffic simulation model, which can imitate the movement of heterogeneous traffic, to analyse the various environment of the road system. The limitation of this study was that only cars, 2W and NMVs were considered during simulation.

Maitra et al. (2003) have captured the mixed traffic operations on roads where partial widening has been done, by modelling of congestion. Using the congestion models, the benefits, if any, from such partial widening have been explored by comparing the congestion and level of service characteristics on selected study roads. But, the limitation of this study was that surface conditions are not considered for the development of congestion models. Bhuyan and Rao (2011) have used average travel speed as the (MOE), which in this case has been derived from second by second speed data obtained from GPS receiver fitted on mobile vehicles. Hierarchical agglomerative clustering (HAC) is implemented on average travel speeds to define the speed ranges of urban street and LOS categories which are valid in Indian context are different from that values specified in HCM (2000). Under limitation of this study is that we need large number of speed data points in order to get better results in classifications.

Although various parameters have been exercized to assess the level of service on urban arterial roads, but the factor 'land use' is still untouched for the determination of LOS till date. Hence this study will carry out the LOS determination with land use as a measure of effectiveness. The study will also find the existing level of service on the selected road section and determine the present traffic conditions, so as to state

if the present conditions full-fill the present demand or any measures are to be taken to overcome the problem eventually to be faced in the future.

3 Data Analysis

3.1 Study Area

The total stretch of 5.7 km has been selected to carry out the study starting from Athwa Gate Circle and ending at Rahul Raj Mall in the city of Surat, Gujarat (Fig. 2; Table 1).

The whole stretch has been divided into six segments as detailed in the above table and google map. AutoCAD drawing of full stretch has also been drawn showing the land use pattern and the section of Athwa Gate to Police Parade Ground has been shown in Fig. 3.
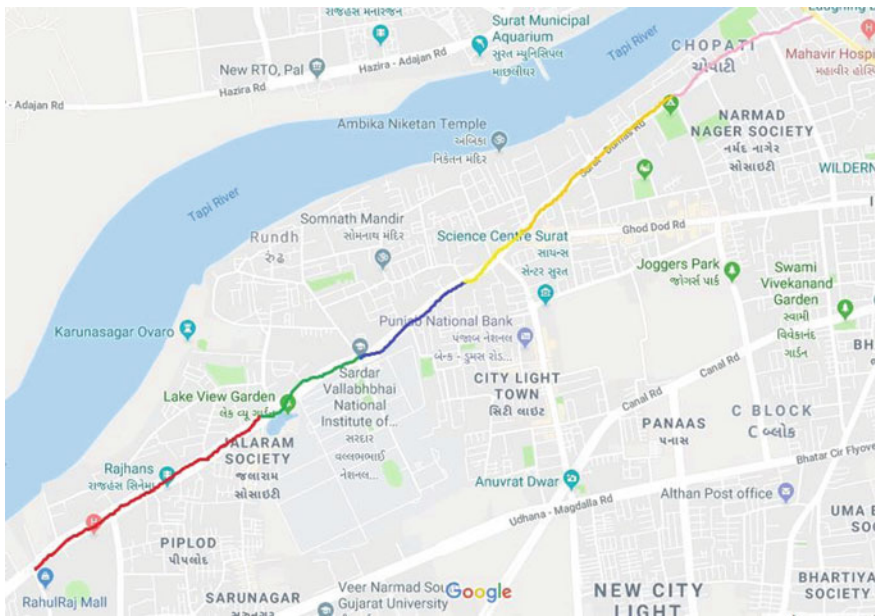

Fig. 2 Google Map of whole stretch from Athwa Gate to Rahul Raj Mall

Table 1 Details of various mid-block sections

Colour	Mid-block section	Distance (km)
	Rahul Raj-Kargil Chowk (RR-KC)	1.59
	Kargil Chowk-SVNIT (KC-SV)	0.67
	SVNIT-Sargam Shopping Centre (SV-SR)	0.76
	Sargam Shopping Centre-Parle Point (SR-PR)	0.42
	Parle Point-Police Parade Ground (PR-PP)	1.22
	Police Parade Ground-Athwa Gate (PP-AG)	0.91
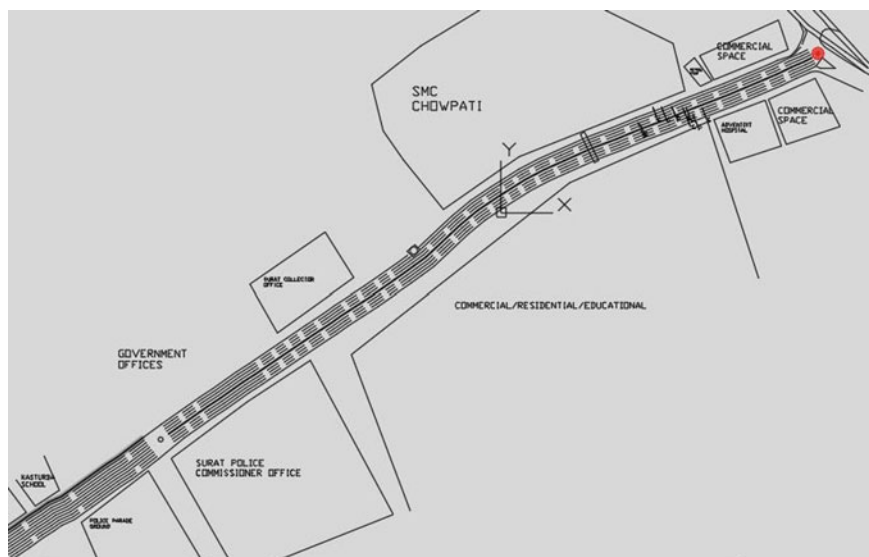
Fig. 3 AutoCAD drawing of Athwa Gate–Police Parade Ground Section

3.2 Data Collection

Data collection mainly comprised of two stages:

1. **Speed Data Collection using V-Box**

Speed data of different categories of vehicles, i.e., two-wheelers, three-wheelers, big and small cars and buses, was collected during this stage. These data were collected during different days and during different periods of time and were categorized into morning peak, off-peak and evening peak hours. In total, 30 samples, in both up and down directions for each vehicle category, were taken for the study (Fig. 4).

2. **Vehicular Volume Count**

Finally, for relating vehicular volume with speed obtained from V-Box, volume count was also done. This count was done for 1 h for each mid-block section for all three time periods, i.e., morning peak, off-peak and evening peak (Fig. 5).

Fig. 4 V-Box speed data collection

Fig. 5 Volume count survey

3.3 V-Box Data Collection

From the speed data collected from V-Box, speed-distance plots were plotted using performance box software for different time period and for different stretches. Below are some sample speed–distance plots of different vehicle categories for the stretch Athwa Gate to Police Parade Ground (Figs. 6, 7 and 8).
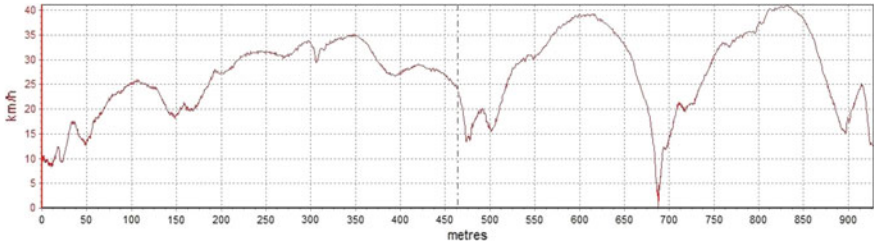
Fig. 6 Variation in speed with space for 2W
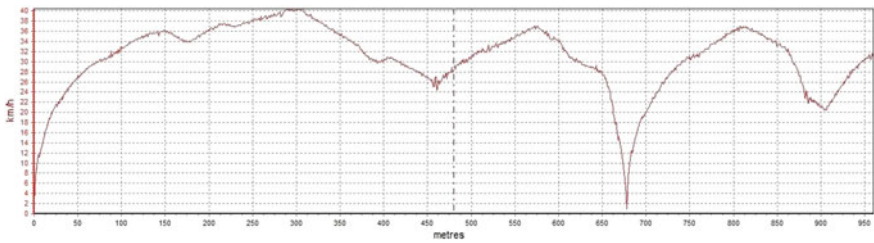
Fig. 7 Variation in speed with space for 3W
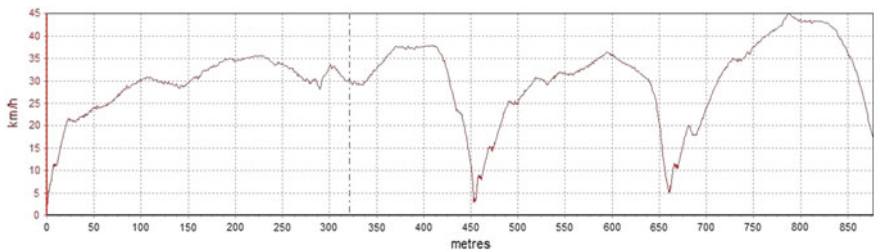
Fig. 8 Variation in speed with space for small car

3.4 Data Analysis

3.4.1 Spatial Variation of Speed

Spatial variation of speed was analysed for each category of vehicle separately for different mid-block sections and cumulative frequency versus mean speed plot has been plotted for each category for different time periods (Figs. 9, 10 and 11).
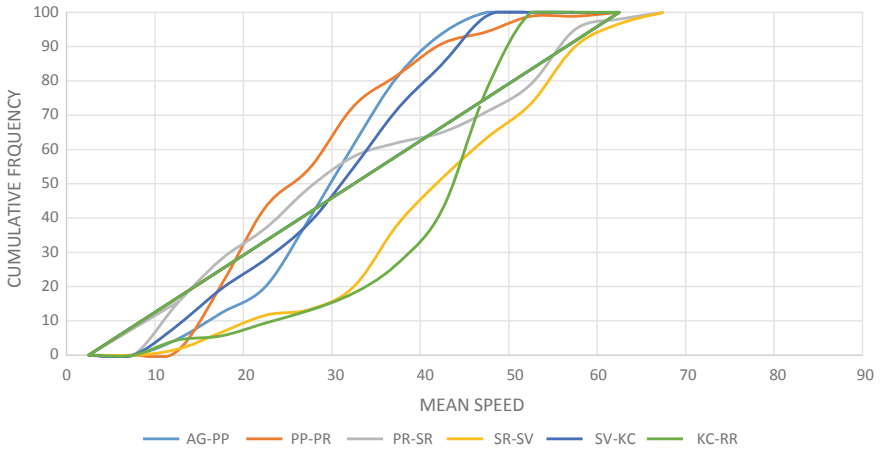
Fig. 9 2 wheeler, Evening Peak
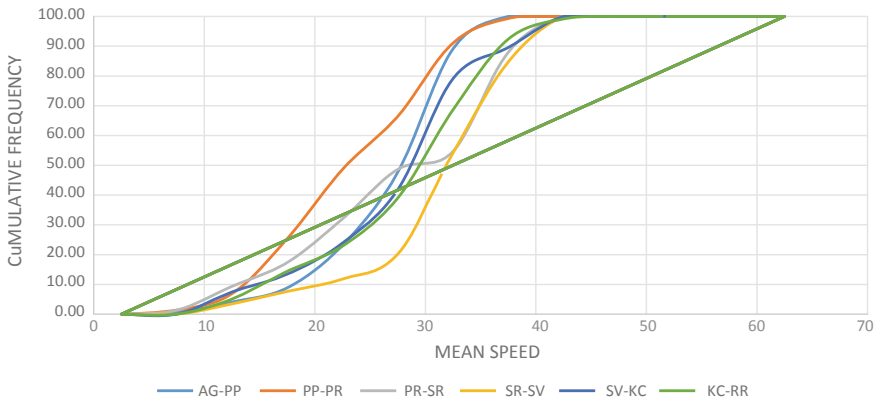
Fig. 10 3W, evening peak
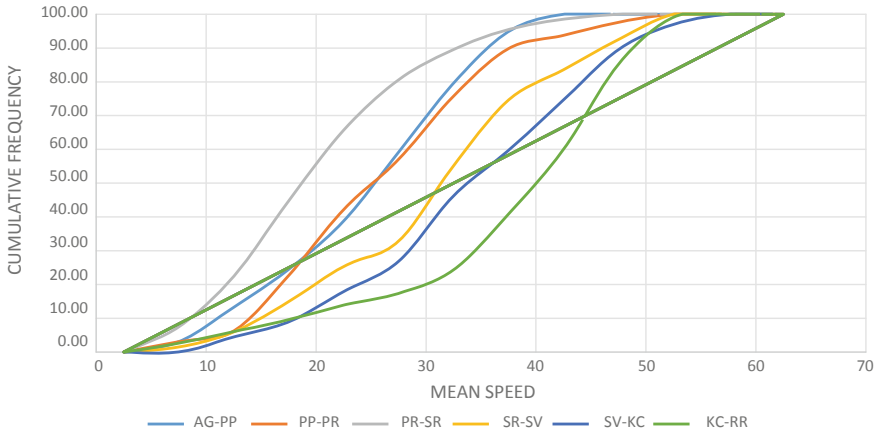
Fig. 11 Small car, evening peak

3.4.2 Temporal Variation

Here, the variation in speed of vehicles was analysed for different period of time, i.e., morning peak, off-peak and evening peak within a particular stretch. Mean speed versus cumulative frequency plots of some samples have been shown here (Figs. 12, 13, 14 and 15).
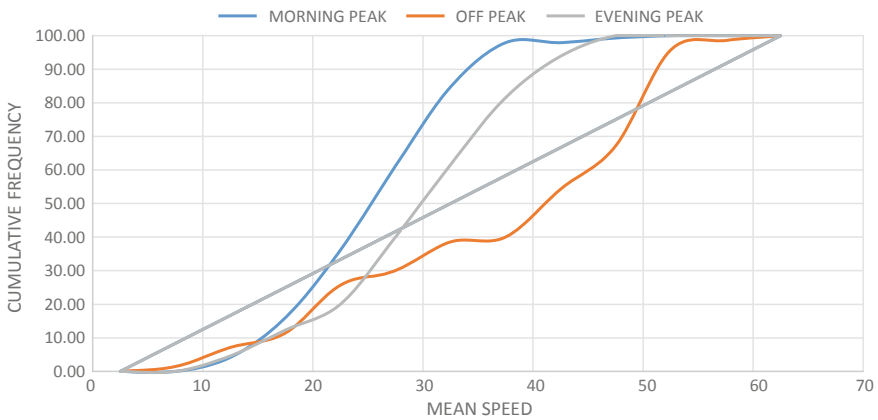
Fig. 12 2W: Athwa Gate–Police Parade Ground
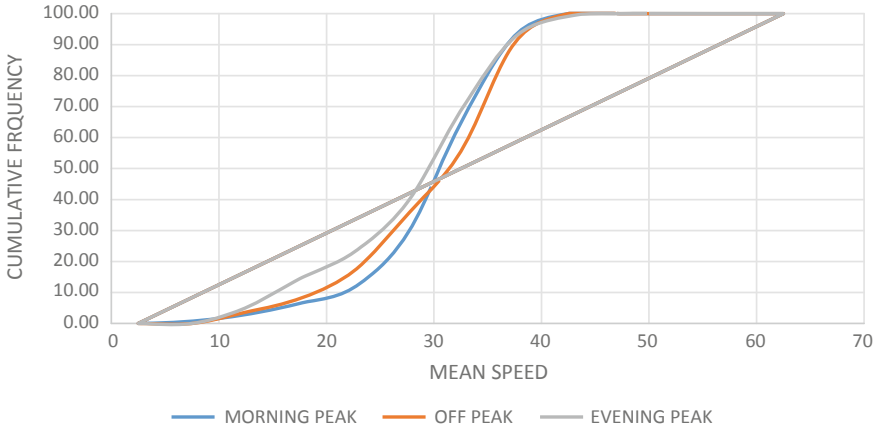
Fig. 13 3W: Kargil Chowk-Rahul Raj
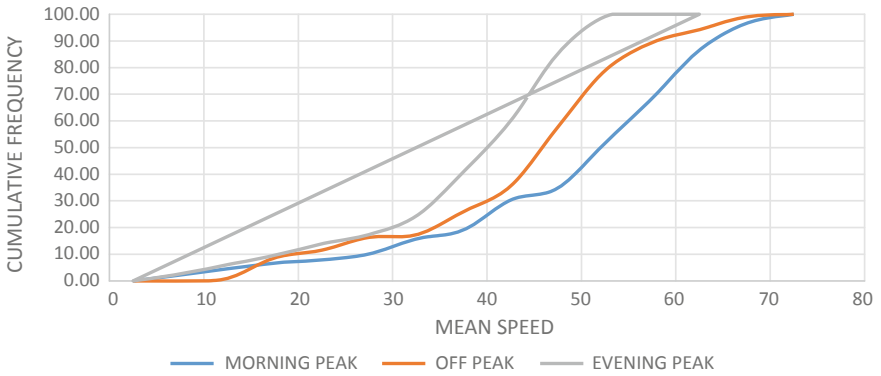
Fig. 14 Small Car: Kargil Chowk-Rahul Raj
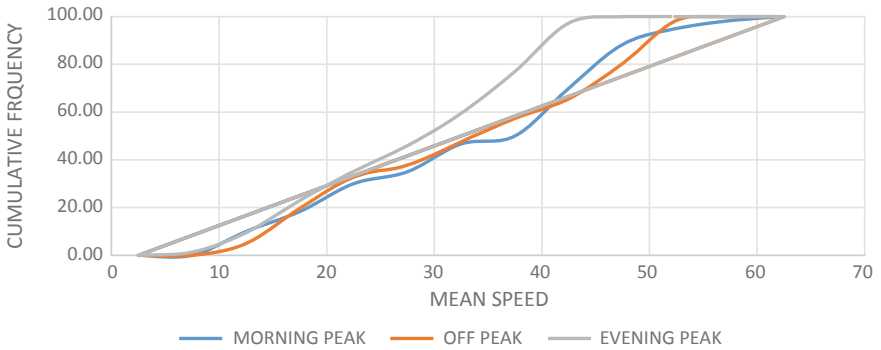
Fig. 15 Big Car: Sargam-SVNIT

3.4.3 Analysis of Speed Data

The speed of different vehicle categories over different mid-block sections was analysed and the excess speed as compared to the posted speed limit was also determined.

Here, excess speed in terms of variation of 85th percentile speed from speed limit is determined and it was found that for most of the stretches and for most of the time, the 85th percentile speed was way below the posted speed limit. Only Rahul Raj-Kargil Cowk and Kargil Chowk-SVNIT have shown some examples of over speeding because of better LOS conditions over there. For remaining stretches, less road width, more frontage access has led to vehicle speed less than posted speed limits.

Such low speeds are not called as good if we talk about operational point of view. But from safety point of view, such values are considered best (Tables 2, 3, 4).

3.4.4 Graphical Comparison of V-Box Speed Data for Different Stretches for Different Time Periods

Some representative samples of different categories of vehicles for a given stretch, for a given period of time, were also plotted on the same graph to analyse the trend of variation of speed among different vehicle categories. Some of them are shown below (Figs. 16, 17 and 18).

3.4.5 V-Box Data Versus Data from Volume Count

The speed data obtained from V-Box survey was compared with the speed data observed in the field through video graphic survey. In total, 30 samples for each category of vehicles were taken for collecting GPS speed data through V-Box. Ten samples each were taken for each duration.

Also, speed data was collected by marking 100 m stretch within each mid-block section for each category. Now, average of both speed data has been taken and statistical test ANOVA has been applied between the data to check if there is any significant difference between the data or not. Finally, it has been found that the speed data obtained from GPS or V-Box and the field data of speed obtained through video graphic survey are almost the same.

Table 2 Morning peak

Segment	Category	Morning peak				
		Speed limit	Mean speed	S D	85th percentile speed	Excess speed
AG-PP	2W	50	27.52	7.22	34.88	−15.12
	3W	35	29.08	5.67	34.36	−0.64
	SC	60	28.91	9.03	38.31	−21.69
	BC	60	28.33	9.24	38.69	−21.31
	HV	40	20.96	7.48	28.88	−11.12
PP-PR	2W	50	25.64	9.47	33.63	−16.37
	3W	35	24.94	6.92	32.65	−2.35
	SC	60	25.65	8.15	34.89	−25.11
	BC	60	26.98	9.03	36.5	−23.5
	HV	40	20.28	7.41	28.64	−11.36
PR-SR	2W	50	32.29	16.8	52.57	2.57
	3W	35	26.72	8.86	37.8	2.8
	SC	60	20.05	7.75	28.7	−31.3
	BC	60	23.42	7.52	32.22	−27.78
	HV	40	16.36	6.64	22.79	−17.21
SR-SV	2W	50	40.06	12.8	53.33	3.33
	3W	35	35.19	8.1	41.46	6.46
	SC	60	35.57	14.3	52.59	−7.41
	BC	60	35.34	13.8	46.79	−13.21
	HV	40	25.61	9.89	35.48	−4.52
SV-KC	2W	50	33.62	11.8	46.74	−3.26
	3W	35	29.7	9.44	39.95	4.95
	SC	60	40.6	15.6	58.45	−1.55
	BC	60	40.13	14	50.03	−9.97
KC-RR	2W	50	42.03	10.3	50.85	0.85
	3W	35	31.95	6.65	38.49	3.49
	SC	60	50.75	15.3	64.29	4.29
	BC	60	49.59	15.7	65.49	5.49

Table 3 Off-peak

| Segment | Category | Off-peak | | | | |
		Speed limit	Mean speed	S D	85th percentile speed	Excess speed
AG-PP	2W	50	39.34	14.1	53.38	3.38
	3W	35	28.61	6.1	35.26	0.26
	SC	60	26.6	9.75	37.62	−22.38
	BC	60	28.68	7.92	36.36	−23.64
	HV	40	20.29	7.14	28.1	−11.9
PP-PR	2W	50	27.23	12	37.61	−12.39
	3W	35	27.03	7.12	33.66	−1.34
	SC	60	29.92	10.5	40.58	−19.42
	BC	60	29.83	8.35	39.28	−20.72
	HV	40	19.32	6.58	26.42	−13.58
PR-SR	2W	50	30.66	6.54	37.43	−12.57
	3W	35	28.99	5.84	35.19	0.19
	SC	60	33.97	16.6	50.26	−9.74
	BC	60	24.45	6.95	31.05	−28.95
	HV	40	20.14	7.77	30.57	−9.43
SR-SV	2W	50	30.81	9.69	41.24	−8.76
	3W	35	30.77	5.66	35.69	0.69
	SC	60	45.52	10.7	53.75	−6.25
	BC	60	34.9	13.6	50.6	−9.4
	HV	40	24.9	11.5	37.5	−2.5

(continued)

Table 3 (continued)

Segment	Category	Off-peak				
		Speed limit	Mean speed	S D	85th percentile speed	Excess speed
SV-KC	2W	50	30.64	14	45.22	−4.78
	3W	35	30.21	8.66	39.22	4.22
	SC	60	41.76	13.5	51.49	−8.51
	BC	60	37.31	13.7	52.18	−7.82
KC-RR	2W	50	40.68	8.75	49.43	−0.57
	3W	35	32.12	7.43	39.25	4.25
	SC	60	45.47	13.3	56.86	−3.14
	BC	60	44.11	15	57.18	−2.82

Table 4 Evening peak

Segment	Category	Evening peak				
		Speed limit	Mean speed	S D	85th percentile speed	Excess speed
AG-PP	2W	50	31.84	8.91	40.5	−9.5
	3W	35	28.92	6.14	34.37	−0.63
	SC	60	26.82	8.83	35.89	−24.11
	BC	60	28.3	8.65	36.67	−23.33
	HV	40	23.97	8.84	33.21	−6.79
PP-PR	2W	50	29.81	10.5	41.33	−8.67
	3W	35	25.67	7.5	34.05	−0.95
	SC	60	28.03	9.76	37.44	−22.56
	BC	60	27.08	8.62	36.55	−23.45
	HV	40	22.07	7.69	29.12	−10.88
PR-SR	2W	50	34.43	17.5	55.85	5.85
	3W	35	29.97	9.33	39.65	4.65
	SC	60	22.4	9.12	32.61	−27.39
	BC	60	22.04	7.36	30.46	−29.54
	HV	40	21.37	8.43	29.44	−10.56
SR-SV	2W	50	44.34	13.3	58.6	8.6
	3W	35	33.18	6.97	39.99	4.99
	SC	60	33.26	11	45.36	−14.64
	BC	60	30.26	10.7	41.78	−18.22
	HV	40	26.18	10.9	37.79	−2.21

(continued)

Table 4 (continued)

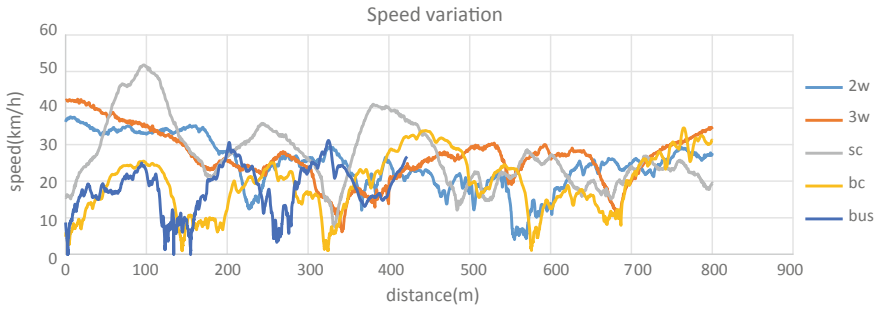| Segment	Category	Evening peak				
		Speed limit	Mean speed	S D	85th percentile speed	Excess speed
SV-KC	2W	50	31.98	11	44.98	−5.02
	3W	35	29.74	7.96	37.48	2.48
	SC	60	36.01	10.9	46.22	−13.78
	BC	60	36.3	12.2	47.85	−12.15
KC-RR	2W	50	42.79	10.4	50.77	0.77
	3W	35	30.5	7.95	37.75	2.75
	SC	60	39.68	11.5	49.65	−10.35
	BC	60	41.63	10.2	50.93	−9.07

Fig. 16 Police Parade–Parle Point, Morning Peak
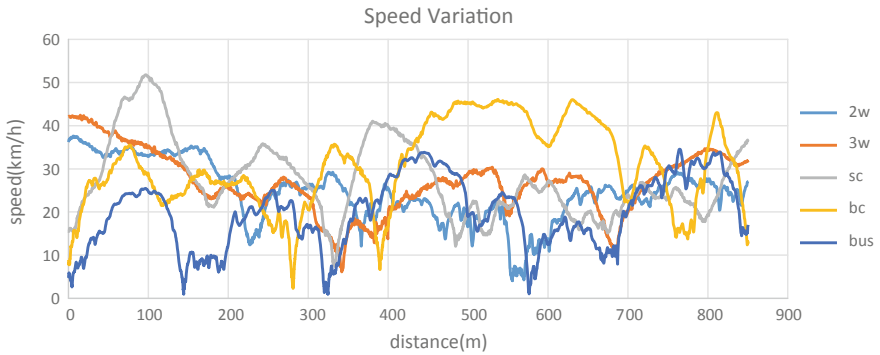
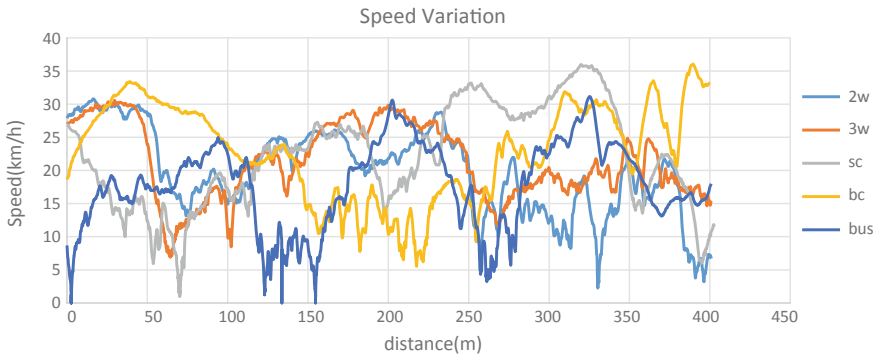
Fig. 17 Athwa Gate–Police Parade Ground, Evening Peak

Fig. 18 Parle Point–Sargam, Morning Peak

Time	Duration	Morning-peak		Evening-peak		Off-peak mode	
		V-Box	V field	V-Box	V field	V-Box	V field
2W	AG-PP	30.15	32.1	28.25	29.3	38.33	40.2
	PP-PR	33.42	35.02	28.65	29.66	33.62	36.6
	PR-SR	31.09	30.22	32.03	30.19	36.85	35.15
	SR-SV	38.58	40.12	40.41	38.22	49.18	53.7
	SV-KC	41.23	43.71	38.69	40.61	48.26	50.01
	KC-RR	46.79	47.87	48.7	47.2	45.52	45.57
	Average	36.87667	38.17333	36.12167	35.86333	41.96	43.53833
	Variance	42.16183	47.71079	63.54626	54.07003	42.66732	55.78374
	p-value	0.744520481		0.954621309		0.704971773	
3W	AG-PP	28.63	30.23	23.56	25.6	30.11	30.32
	PP-PR	30.88	29.45	29.01	30.22	31.21	32.1
	PR-SR	24.8	23.22	22.15	23.06	28.28	30.22
	SR-SV	35.75	36.17	34.2	33.21	37.85	39.6
	SV-KC	35.04	36.22	34.32	35.23	39.05	38.56
	KC-RR	28.88	29.32	27.03	27.77	28.22	27.46
	Average	30.66333	30.76833	28.37833	29.18167	32.45333	33.04333
	Variance	17.35395	24.0003	26.68414	21.23678	23.00299	24.17495
	p-value	0.968884404		0.782013651		0.837576091	
SC	AG-PP	30.66	32.53	28.29	30.36	34.65	34.19
	PP-PR	31.26	31.92	30.35	32.26	35.56	36.98

(continued)

(continued)

Time	Duration	Morning-peak		Evening-peak		Off-peak mode	
		V-Box	V field	V-Box	V field	V-Box	V field
	PR-SR	30.25	30.45	29.35	30.22	34.56	35.62
	SR-SV	38.87	39.65	36.78	37.88	47.69	49.16
	SV-KC	47.29	50.72	39.59	40.73	51.12	52.42
	KC-RR	58.56	58.41	45.53	45.69	48.69	48.28
	Average	39.48167	40.61333	34.98167	36.19	42.045	42.775
	Variance	131.1937	132.8003	46.7369	39.75848	62.22883	64.51551
	p-value	0.867935178		0.756843467		0.876964227	
BC	AG-PP	30.72	32.79	28.52	31	38.62	39.12
	PP-PR	25.79	25.42	25.9	27.21	30.36	31.76
	PR-SR	22.51	24.71	24.12	25.44	30.25	31.33
	SR-SV	41.35	43.22	39.56	40.23	43.55	43.21
	SV-KC	45.79	48.73	37.97	40.33	44.34	46.22
	KC-RR	55.55	55.64	45.37	45.37	46.28	47.16
	Average	38.198	39.544	33.57333	34.93	38.908	39.81943
	Variance	192.1843	194.1279	73.62279	66.2694	42.25261	40.64581
	p-value	0.882087603		0.784464828		0.795620151	
BUS	AG-PP	26.98	29.72	25.19	26.57	32.33	34.61
	PP-PR	28.65	30.26	28.21	29.31	32.56	33.12
	PR-SR	25.16	25.2	22.12	22.96	30.26	30.99
	SR-SV	26.63	28.95	25.56	25.99	35.56	34.09

(continued)

(continued)

Time						
Duration	Morning-peak		Evening-peak		Off-peak mode	
	V-Box	V field	V-Box	V field	V-Box	V field
Average	26.855	28.5325	25.27	26.2075	32.6775	33.2025
Variance	2.053767	5.224758	6.218867	6.783492	4.762558	2.556892
p-value	0.260040817		0.621694222		0.711333977	

4 Results and Conclusions

It was found that among all six mid-block sections, the Rahul Raj-Kargil Chowk, Kargil Chowk-SVNIT and SVNIT-Sargam possess comparatively better level of service with respect to other stretches. It is so because the land use pattern along these stretches is not very much congested and commercialise. Also, availability of service lane, cycle lane, six-lane roads which are not available in other stretch enhances user experience on these stretches.

If we talk about temporal variation, then speed variations were more in morning peak and evening peak hours as compared to off-peak hours. But it was also observed that since the speed of three-wheelers was restricted by administration, there was not very much difference in the speed values for different times of the day. Although the cumulative speed plots for small cars and big cars clearly represent the effect of peak and non-peak hours on vehicle speed. Two-wheelers also can manoeuvre easily in any time of the day owing to their small size and easy navigation.

Excess speed in terms of variation of 85th percentile speed from speed limit was also determined and it was found that for most of the stretches and for most of the time, the 85th percentile speed was way below the posted speed limit. Only Rahul Raj-Kargil Chowk and Kargil Chowk-SVNIT has shown some examples of over speeding because of better LOS conditions over there. For remaining stretches, less road width, more frontage access has led to vehicle speed less than posted speed limits.

On plotting the speed variation of different vehicles on same speed-distance graph, it was found that the total variation was minimum for two-wheeler category owing to their easy manoeuverability even in more traffic. On the other hand, the speed variation of bus was maximum.

ANOVA of data obtained from V-Box and data obtained from videographic survey indicate that there is not much difference between the two data.

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