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Accuracy of Traffic Volume and Classification Data Collection at Signalized Urban Intersections

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ABSTRACT*: Indian traffic is heterogenous in nature. Conducting traffic analysis with such multiple modes and sizes of vehicles is complex. The most important aspect of any analysis is the data. Obtaining good traffic data is necessary for conducting intersection analysis. However, field observations and literature review has indicated that the accuracy of traffic data collection at urbanized intersections in India varies. This paper illustrates the various traffic volume data collection methods and the complexities in the Indian context. The paper also documents the accuracy for traffic volume data at signalized urban intersections, and identifies the most suitable method for such purpose.*

KEYWORDS – *Accuracy, Comparison, Signalized Urban Intersections, Traffic Volume Data*

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I. INTRODUCTION

Indian traffic is heterogenous in nature. The traffic involves multiple modes such as 2-wheelers, 3-wheelers, 4-wheelers (such as cars), large vehicles such as trucks / buses, non-motorized vehicles such as bicycles, rickshaws, animal drawn vehicles, push carts, etc. The size of the vehicles also varies considerably even among such modes. Thus, it becomes a complex process to analysis such situation.

For any analysis, good data is important. The data shall be accurate to the extent possible, usually should be 100% accurate, but based on the need, as close to 100% accuracy as possible. Based on field observations of the traffic at urban signalized intersections, it can be stated that obtaining traffic volume data is not that simple. Further, literature review also did not yield specifics about the quality of the traffic volume data at urban intersections. Against this backdrop, this paper illustrates the various traffic volume data collection methods, the complexities in such data, and the accuracy for the data collection.

Several reports and papers were found related to traffic data collection. However, very few reports or papers are available related to traffic volume data collection at intersections, specifically related to heterogenous traffic conditions. Nipjyoti Bharadwaj, et al. [1] have compared an image processing tool vs manual data, for mid-block volume and other parameters, for heterogenous traffic conditions of India. According to them, the image processing data was only about 78% accurate for volume counts in fully automatic modes. However, through manual intervention, it was stated that up to 100% accuracy is possible. The peak hour traffic volume was observed to be about 6,958 vehicles. C. Mallikarjuna, et al. [2] have compared an image processing tool vs manual data for mid-block and other parameters for heterogenous traffic conditions of India. According to them, the image processing data accuracy varied from 67% to 100% for various modes of traffic. The peak hour traffic volume was observed to be about 2,860 vehicles. Similarly, several studies compared the traffic data collection, but most of such studies are related to mid-block or for homogenous traffic conditions, which are not applicable for signalized urban intersections.

II. TRAFFIC VOLUME DATA COLLECTION ASPECTS

Traffic data is obtained at different locations based on the purpose of the analysis or the study. The different locations include highways, toll plaza, mid-block, intersections, etc. This paper and its corresponding literature review / analysis is limited to urban signalized intersections; hence, the traffic volume data collection is also limited for urban signalized intersections only. Other forms of traffic data collection such as speeds, delays, etc., are not included in this paper. The uniqueness of traffic volume data collection at intersection is that it requires multiple input to be observed as noted below:

- Mode of vehicle (for ex. 2-wheeler, 3-wheeler, car, etc.)
- Approach Direction of vehicle

- Departure Direction of vehicle
- Number of vehicles for such mode

Usually, for most purposes, the traffic volume at intersections is obtained in 15-minutes interval over a period of 2 to 3 hours. For a 4-legged intersection, the following four directions exist for each of the legs:

- Left
- Through (i.e., straight)
- Right
- U-turn

Hence, one has to obtain traffic data for 16 unique movements. If, for illustration, 6 modes of traffic are considered, this would result in 96 records of data for each 15-minutes interval. It's noted that since the intersection is signalized, usually only 7 unique movements would be functional at any given point of time (i.e., considering the 4 directions of each leg, plus free left turns for the remaining legs). Even then, it would result in about 7 movements x 6 modes = 42 records of data at any given point of time.

III. TRAFFIC VOLUME DATA COLLECTION METHODS

Several methods exist for traffic volume data collection at mid-blocks. However, when intersections are involved, this results in vehicular turning movements, which eliminates most of the mid-block methods. Further, a few advanced technologies are utilized in developed countries, but use of such technology in India was not found. A detailed search of various research and internet information has revealed the following techniques to be in use in India for traffic volume counts at intersections:

- Manual Data Collection
- Video Data Collection with manual data extraction
- Video Data Collection with semi-automatic software data extraction
- Video Data Collection with fully automatic software data extraction

3.1 Manual Data Collection

This method is a time-tested method. In this method, enumerators are used to count the traffic volume and record the data. Thus, manually each of the directions of the intersections, for each mode separately are counted and recorded. As stated earlier, for the illustration stated above, 42 records of data have to be monitored at any given point of time. Thus, based on the traffic volume, the number of enumerators could be high. Practically, about 30 to 40 enumerators are deployed at the intersection, with additional helpers / relievers. The data so obtained is recorded on paper, which is then added up, for further analysis. Alternatively, traffic turning movement recorders are available, which would save the time of adding up the data. A newer system is the use of certain software / applications on mobile phones, which act similar to the traffic turning movement recorders. The following figures show the typical forms of manual data collection and the recording machines.

Date: **Location:** **Time:**		**Movement:** Left Straight Right U-Turn		**Direction From:**	
2-Wheeler	**Auto Rickshaw**	**Car**	**Light Cargo Vehicle**	**Bus**	**Truck**

Figure 1: Manual Traffic Data Collection Form

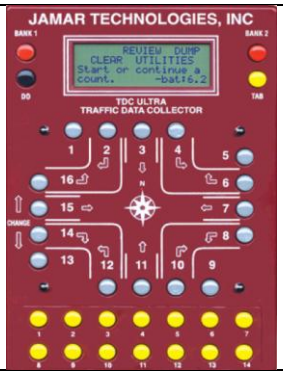
Recording Machine	Recording Software for Mobile
	
Source: Jamar Technologies at www.jamartech.com	Source: www.trafdata.com

Figure 1: Manual Traffic Data Collection through Machine / Software

Table 1: Pros and Cons of Manual Data Collection

Pros	Cons
▪ Usually low cost ▪ Costly equipment is not required ▪ Quicker to conduct	▪ Prone to human error ▪ No proof of data ▪ Cannot verify any information ▪ Requires high number of enumerators ▪ Risk of accident as the enumerators are standing on the side of the road

3.2 Video Data Collection through Manual Data Extraction

This method involves use of videos to record the traffic data. Afterwards, the video is played back and enumerators would manually count the data from the video.

Video Camera	Intersection Layout in Video
	
Source: Traffic Data & Control at http://trafficdc.com.au	Source: Traffic Data & Control at http://trafficdc.com.au

Figure 2: Video Traffic Data Collection

Table 2: Pros and Cons of Video Data Collection and Manual Extraction

Pros	Cons
▪ Less risk to field personnel as 1 or 2 persons are involved for field installation of video camera ▪ All data is recorded, and hence can be re-verified	▪ Requires back-end data enumerators and play back through TV or computers, hence, costly ▪ Time taking to extract data ▪ Prone to human error during data extraction

3.3 Video Data Collection through Semi-Automatic Software Data Extraction

This method involves use of videos to record the traffic data. Afterwards, the video is played back, while a software counts the data from the video, and provides the data in a spreadsheet. A human observer keeps watching the video, while the software identifies and counts the vehicles. However, when the human observer notices any mis-identification by the software, he would pause the video and re-identify the vehicle. Hence, this is also a labor-intensive task.

3.4 Video Data Collection through Fully-Automatic Software Data Extraction

A fully automatic system is where the software can identify and count the vehicles. This can happen real time or even from a recorded video. Here, human intervention is not required.

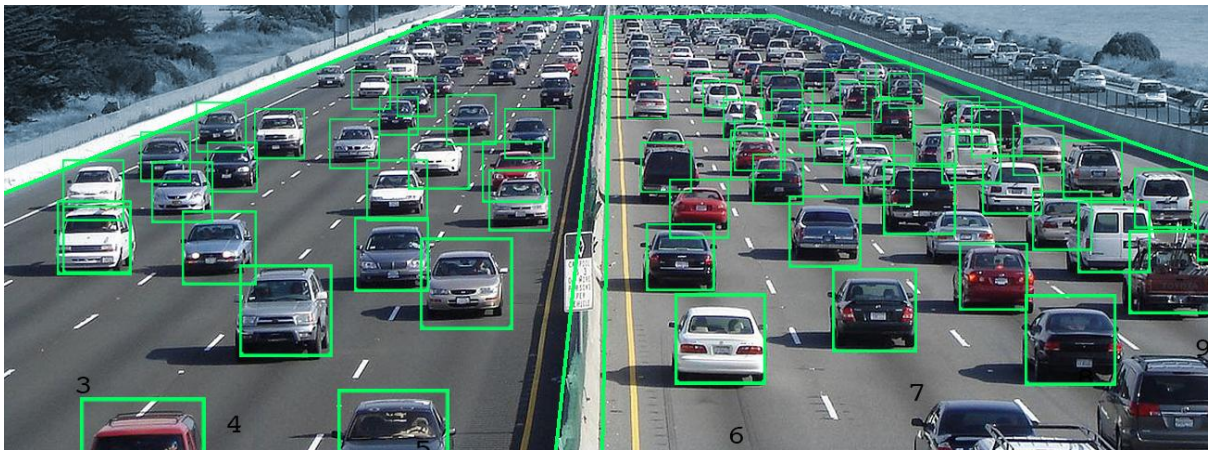


Figure 3: Automatic Traffic Data Collection

Source: www.trafficvision.com

Table 3: Pros and Cons of Video Data Collection and Software Extraction

Pros	Cons
▪ Less risk to field personnel as 1 or 2 persons are involved for field installation of video camera ▪ All data is recorded, and hence can be re-verified	▪ Requires back-end software, hence costly ▪ Software can mis-identify vehicles ▪ Software accuracy is still not high ▪ Requires video to cover entire intersection for higher accuracy, which is difficult in most cases ▪ Not much success for intersection counts

Numerous studies and reports have been published about the data collection for mid-block. But for intersections, such studies fail to be specific. The accuracy of the data collection at intersections varied across multiple studies. Further, new technology are available such as Fish Eye Camera or drones for the purpose of traffic data collection at intersections. However, such technology is not yet commercially available in India, and would also be cost prohibitive in the near future.

IV. TRAFFIC VOLUME DATA COLLECTION

For the purpose of this study, the traffic volume data at four intersections was obtained for different modes of traffic and for the different turning movements at intersections in Hyderabad, India. Video data collection through software data extraction was not possible, since suitable equipment was not available commercially that could capture the entire intersection. When attempts were made to install camera to cover the entire intersection, several vehicles were not visible in any one camera due to the angle of the camera, and larger vehicles were camouflaging smaller vehicles. Hence, data was obtained through two methods: Manual data collection, and Video data collection with manual data extraction. Even in this case, multiple video cameras were installed, where in certain movements were captured in one camera, while other cameras captured other movements. Since it was a human extracting the data, it was possible to understand the movement of the vehicles to various directions, even though the entire intersection was not covered in a single camera.

V. ERROR CALCULATION

For the purpose of this paper, the "base line" data was considered as Video data collection through manual data extraction. The data obtained through video counts was compared to the manual data collection to determine the accuracy of the data collection. An interesting aspect is the establishment of the video data

through manual data extraction to be accurate. As noted earlier, this method involves a human element, which is prone to human error. Hence, the following procedure was followed:

- Video data was time stamped and the directions of the traffic was clearly identified
- A common training session was conducted for the enumerators to identify the vehicles
- Each video data was subjected to two separate counts independently
- If there was more than 1% error in the video extracted data, the data extraction was conducted again
- The final data from the video was considered to be accurate only after two independent counts were found to be within 1% accuracy

The following observations were made in the extraction of the data from videos:

- Initially the data obtained by two independent counts varied by about 29%
- Even after repeated counts, the errors reduced to about 10%
- It was observed that commercial enumerators were interested in completing the job of counting, rather than the accuracy
- Only when it was reiterated that the data was for research purpose and that the video data accuracy was important, and with periodic supervision, the data accuracy with error of 1% was achieved

Whether through manual data collection or through video data collection, the following are key practical limitations to the data accuracy:

- Due to visibility of the observer / camera, certain vehicles would be missed out
- At lower volumes, accuracy was high, while at higher volumes, the accuracy was significantly low
- For ex. When the traffic signal was red, motor bikes / scooters would start piling up at the stop bar. The moment the traffic signal turned green, all the motor bikes / scooters would attempt to leave at once. At the sites studied, about 50 to 60 motor bikes / scooters were observed to leave within 2 to 3 seconds. Thus, expecting a human to count about 15 to 20 vehicles in 1 second is impractical, and probably impossible

VI. DATA COMPARISON

Traffic data was obtained for four different intersections in Hyderabad, through video counts which were manually extracted and through manual counts. The data was limited to 2-hours in the morning peak hours and 2-hours in the evening peak hours. The specific peak hour varied across the intersections. The data was collected for the following modes of traffic:

- Motorized 2-wheelers
- 3-Wheelers
- Cars
- Light Vehicles
- Medium Vehicles
- Heavy Vehicles

The data was obtained for all the movements of the intersections (i.e., left / through / right / u-turn). The data was codified from the direction of origin (for example: eastbound turning left as EBL). Both the video counts and the manual counts were compared for accuracy, by considering the video counts as the base counts. As noted earlier, video counts were counted at least two times to obtain matching numbers.

The data accuracy pointed out both negative errors and positive errors, i.e., in some cases the manual counts were lower than the video counts, while in others, the manual counts were higher than the video counts. For the purpose of simplicity, the absolute errors were considered, i.e., the positive / negative sign was not considered.

Further, it was noticed that there was some difference in the errors based on the mode of the vehicle or the turning movements. Hence, the data was tabulated accordingly. The following tables show the errors by the turning movements.

Table 4: Errors for Left Turn Movement

Direction	Movement	Two-Wheelers	Three-Wheelers	Cars	Light Vehicles	Medium Vehicles	Heavy Vehicles	Average Error
Biodiversity Junction	EBL	11.05%	9.83%	11.92%	10.96%	12.12%	10.96%	**11.14%**
	SBL	10.06%	9.94%	10.16%	4.97%	2.59%	0.00%	**6.29%**
Hitec City Junction	EBL	5.75%	7.75%	6.97%	5.39%	7.01%	7.29%	**6.69%**
	WBL	9.72%	9.37%	8.50%	0.00%	1.25%	0.00%	**4.81%**
	NBL	9.30%	7.62%	7.05%	1.25%	1.25%	0.00%	**4.41%**
	SBL	8.89%	8.42%	8.99%	7.77%	6.30%	7.81%	**8.03%**
Paradise Junction	EBL	9.71%	9.44%	9.96%	1.25%	2.86%	0.00%	**5.54%**
	WBL	9.27%	9.18%	9.26%	4.96%	4.63%	0.00%	**6.22%**
	NBL	6.31%	7.59%	5.30%	0.00%	0.00%	0.00%	**3.20%**
	SBL	8.38%	8.00%	8.51%	6.29%	7.45%	0.00%	**6.44%**
Wipro Junction	EBL	8.43%	8.80%	8.10%	2.98%	0.89%	0.00%	**4.87%**
	WBL	7.49%	9.53%	8.26%	0.00%	0.00%	0.00%	**4.21%**
	NBL	4.24%	2.20%	7.24%	0.00%	0.00%	0.00%	**2.28%**
	SBL	8.63%	6.74%	7.85%	0.00%	0.00%	0.00%	**3.87%**
Average Error		**8.37%**	**8.17%**	**8.43%**	**3.27%**	**3.31%**	**1.86%**	**5.57%**

Table 5: Errors for Through Movement

Direction	Movement	Two-Wheelers	Three-Wheelers	Cars	Light Vehicles	Medium Vehicles	Heavy Vehicles	Average Error
Biodiversity Junction	EBT	12.85%	14.71%	13.81%	8.80%	14.39%	0.00%	**10.76%**
	WBT	11.94%	12.89%	12.57%	10.05%	11.71%	5.16%	**10.72%**
Hitec City Junction	EBT	14.49%	14.22%	12.99%	10.49%	15.99%	0.00%	**11.36%**
	WBT	16.77%	15.10%	15.63%	15.25%	15.90%	11.41%	**15.01%**
	NBT	8.91%	7.21%	8.03%	3.87%	7.89%	0.00%	**5.98%**
	SBT	9.69%	8.84%	9.88%	0.00%	1.73%	0.00%	**5.02%**
Paradise Junction	EBT	7.97%	8.68%	9.31%	9.02%	8.50%	5.57%	**8.18%**
	WBT	8.88%	9.59%	9.18%	2.46%	9.32%	5.65%	**7.51%**
	NBT	9.59%	10.83%	9.30%	1.56%	0.00%	0.00%	**5.21%**
	SBT	11.35%	11.30%	11.82%	3.71%	5.42%	0.00%	**7.27%**
Wipro Junction	EBT	5.37%	1.67%	7.88%	0.00%	1.79%	0.00%	**2.78%**
	WBT	7.51%	4.78%	7.43%	0.00%	1.93%	0.00%	**3.61%**
	NBT	10.54%	9.30%	10.52%	7.50%	7.49%	0.00%	**7.56%**
	SBT	10.19%	10.37%	11.80%	11.14%	10.93%	0.00%	**9.07%**
Average Error		**10.43%**	**9.96%**	**10.72%**	**5.99%**	**8.07%**	**1.98%**	**7.86%**

Table 6: Errors for Right Turn Movement

Direction	Movement	Two-Wheelers	Three-Wheelers	Cars	Light Vehicles	Medium Vehicles	Heavy Vehicles	Average Error
Biodiversity Junction	WBR	15.30%	15.22%	14.86%	14.92%	14.50%	11.46%	**14.38%**
	SBR	13.42%	12.34%	13.43%	12.15%	11.76%	2.08%	**10.86%**
Hitec City Junction	EBR	14.71%	15.60%	14.37%	9.91%	13.81%	12.04%	**13.41%**
	WBR	12.94%	13.65%	12.70%	2.84%	11.17%	9.69%	**10.50%**
	NBR	8.00%	8.19%	7.66%	5.23%	4.48%	0.00%	**5.59%**
	SBR	12.27%	13.52%	12.69%	14.30%	3.13%	3.39%	**9.88%**
Paradise Junction	EBR	7.00%	8.39%	8.59%	1.64%	0.00%	0.00%	**4.27%**
	WBR	9.04%	7.36%	8.62%	4.41%	9.94%	6.96%	**7.72%**
	NBR	8.96%	8.55%	8.79%	3.46%	4.08%	0.00%	**5.64%**
	SBR	11.62%	9.91%	9.96%	9.59%	3.93%	0.00%	**7.50%**
Wipro Junction	EBR	8.57%	0.00%	9.89%	0.00%	0.00%	0.00%	**3.08%**
	WBR	7.54%	2.04%	6.64%	0.00%	2.03%	0.00%	**3.04%**
	NBR	10.01%	10.52%	10.13%	2.99%	6.43%	1.56%	**6.94%**
	SBR	8.98%	9.62%	9.88%	0.00%	7.39%	0.00%	**5.98%**
Average Error		**10.60%**	**9.64%**	**10.59%**	**5.82%**	**6.62%**	**3.37%**	**7.77%**

Table 7: Errors for U-Turn Movement

Direction	Movement	Two-Wheelers	Three-Wheelers	Cars	Light Vehicles	Medium Vehicles	Heavy Vehicles	Average Error
Biodiversity Junction	EBU	9.12%	3.54%	8.91%	0.00%	0.00%	0.00%	**3.59%**
	WBU	9.28%	6.11%	8.56%	1.95%	2.69%	1.56%	**5.03%**
	SBU	8.23%	3.92%	7.98%	1.25%	0.00%	0.00%	**3.56%**
Hitec City Junction	EBU	5.94%	5.23%	4.45%	0.00%	0.00%	0.00%	**2.60%**
	WBU	5.18%	8.20%	7.35%	0.00%	0.00%	0.00%	**3.45%**
	NBU	9.44%	6.88%	8.66%	3.33%	4.06%	2.60%	**5.83%**
	SBU	9.38%	8.67%	7.25%	0.00%	0.00%	0.00%	**4.22%**
Wipro Junction	NBU	2.21%	0.00%	6.61%	0.00%	0.00%	0.00%	**1.47%**
	SBU	6.92%	6.53%	8.41%	0.48%	0.00%	0.00%	**3.72%**
Average Error		**7.30%**	**5.45%**	**7.57%**	**0.78%**	**0.75%**	**0.46%**	**3.72%**

VII. OBSERVATIONS AND CONCLUSIONS

- The average error for through movements and right turns is similar.
- The left turns error is smaller and the U-turn error is even smaller.
- This difference in error for the movements was based on the situation that comparatively, left turns and U-turn has lower volume, which resulted in ease of counting and hence higher accuracy.
- The average error for 2-wheelers, 3-wheelers and Cars is similar
- The average error for Light Vehicles, Medium Vehicles and Large Vehicles is similar but lower than the other modes
- This difference in error for the modes of the vehicles was based on the situation that comparatively the heavier vehicles volumes were significantly lower, which resulted in ease of counting and hence higher accuracy.

- Across the intersections, the error varied. However, based on traffic volumes, the error was not significantly varying.
- Across the entire data, the errors were found to vary from 0% to about 33%, which is a significant variance
- Across the entire data, the traffic volume in each 15-minute interval for each mode varied from 1 vehicle to about 1,040 vehicles, i.e., 1,040 vehicles in 15-minutes equals 69.33 vehicles per minute. When the signal turns green, about 60 to 70 two-wheelers were observed to leave the intersection in a matter of a few seconds. This is humanly not possible to count. This situation was verified through several field visits.

It can be concluded that in urban signalized intersections with high traffic volumes, i.e., more than about 5,000 vehicles per hour, the traffic errors through manual counts could be as high as about 33%, but could be varying at an average of about 4% to 8%. Further, it is not practically possible to collect high accurate traffic volumes through manual counts.

Further, it is stated that even through video counts with manual extraction, it is difficult to expect high accurate traffic volumes at high traffic volume locations, unless the data is cross verified through multiple independent counts, which is economically not feasible, considering the amount of time and effort required for such repetitive work.

Additionally, it can be stated that obtaining traffic counts for intersections with mixed modes of traffic through entirely automatic methods is not yet at a commercially viable stage. It is recommended that the need for accuracy is assessed prior to taking up the traffic data collection. Further research could review the sensitivity impact of accuracy for various analysis.

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