Traffic Congestion "Gap" Analysis in India

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Abstract: This study is more than one-month traffic flow observation in India and introduces new traffic congestion "Gap" from the analysis of real traffic flow analysis in India. Traffic congestion becomes serious problem especially in developing countries such as India. In general, it is quite challenging to collect traffic data and understand traffic congestion problem from its data analysis. In this study, it is the first time to show long term traffic monitoring at one of major junction in Ahmedabad city of Gujarat state India. IAs for traffic congestion analysis, the following challenges are executed with a collaboration from local city government. Step 1 is to select location for 8 months observation by traffic monitoring camera in the city. Step 2 is to analyse traffic flow at the junction from each direction traffic flow. Step 3 is to evaluate traffic congestion with traffic flow parameter from traffic flow theory. Step 4 is to analyse geographical mapping by GIS tool. Based on these steps, it reached to unique traffic congestion mechanism in the junction, which it is named congestion "Gap" and large traffic volume is not always a case of traffic congestion. From this result, there is a possibility to improve traffic management when more detail observation at certain time of traffic congestion happing and environmental condition such as traffic signal control, road infrastructure structure and so on.

1 INTRODUCTION

This study is a series of the traffic flow analysis in India under India and Japanese government funded project as Science and Technology Research Partnership for Sustainable Development or "SATREPS", which is an international joint research targeting global issues.

In general, traffic congestion becomes global issue for low carbon scenario especially in developing countries such as India. Developing countries have same kind of problem for traffic management because of budgetary issue. The government faces un-balance between their rapid economic development and infrastructure improvement preparation. In order to find actual problem for transportation, there are so many things to be prepared at the same time－road expiation, enough traffic signal installation, public transportation support, and so on. In transportation study for developing countries, they just started. For example, A. Salim et al. used traffic density and space headway parameters to analyze traffic congestion. And B. Chanda reported vehicle probe data in terms of the traffic volume and speed in Hyderabad, India, based on the Indian Road Standard IRC-106-1990. Those studies based on short time measurement like four days so on.

In this study, we use traffic monitoring camera or traffic monitoring camera for collecting traffic condition on the road such as number of vehicles, average vehicle speed, gap between vehicles, size of vehicles very minute during eight months from January 2019. The monitoring field is the west side of Ahmedabad city of Gujarat state in India, where its population is over 8 million in 2018 from 5 million in 2011 and the number of vehicles is about 4 million in 2017. More than 70% vehicle is two wheelers, which is typical percentage in developing countries. The city profile is shown in Table 1.

Table 1: Profile: Ahmedabad City.

Co-ordinates:	23.03° N 72.58° E
Area:	466 Sq.km. (year 2006)
Population:	55,77,940 (year 2011 Census)
Density:	11,948 /sq.km
Literacy Rate:	89.60 %
Average Annual Rainfall:	782 mm

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In our relted studies, the traffic congestion Tsuboi.T. shows that occupancy parameter is one of capable parameter for traffic congestion condition, especially in India. In general, traffic congestion is caused by large traffic volume and slow vehicle speed. From one-year traffic observation in Ahmedabad city, the peak of traffic volume happens in the morning and the second peak occurs in the evening. However, the congestion occurs in the second peak of traffic volume in the evening, which means large traffic volume is not always main reason for traffic congestion.

From the above general condition, it is focused on the traffic condition at one of major junction where there are four traffic monitoring cameras in each crossroad in order to measure all direction vehicle movement. The other traffic monitoring cameras in the city face one direction of their roads, therefore it is difficult to observe total vehicle movement. In the next Section 2, it is described the environment condition including traffic monitoring camera location and social information data e.g. population in map. In Section 3, it shows measurement data of one-month April 2019 example for eight months monitoring and traffic flow analysis. In Section 4, there is discussion about traffic congestion "Gap", which we find unique traffic flow phenomena analysis result. And then in Section 5, we conclude this study.

Figure 1: Traffic monitoring Field (number indicates traffic monitoring camera location, d circle is Paldi junction location, and red and blue line shows Metro underdevelopment).

2 TRAFFIC OBERVATION FIELD

We choose Ahmedabad city of Gujarat state in India as urban transportation analysis place. The selection reason is that Ahmedabad is one of typical growing city in India and there are negative impact caused by heavy traffic congestion such as air pollution, traffic fatality, accidents, logistic delay and economical loss etc. On the other hand, local government, or Ahmedabad Municipal Corporation (AMC) has lot of improvement challenge such as Buss Rapid Transportation (BRT), Metro development, and high-speed train (Bullet Train) plan and so on.

2.1 Field Environment

The field environment is shown in Figure 1.

- The number is traffic monitoring camera installed location
- Red and Blue line shows Metro (under construction)
- Target junction is Paldi (Camera No.2001 ~ 2004)

In terms of social information, Figure 2 shows 1-kilometer mesh areal interpolation population and traffic monitoring camera location. The dark colour shows denser of population which shows black dot mark. From Figure 2, a greater number of populations is in the east side of the city across the river because the east side is called "old town" and many residents live there. On the other hand, the west side of city is called "new town" and there are new office buildings and shops. Therefore, it is expectable rush hours in the morning and in the evening at Paldi junction.

Here is some assumption about North-South traffic flow direction particularly at Paldi junction from this social environment. This assumption is explained in Section 3 later.

- People movement from North to South in the morning
- People movement from South to North in the evening

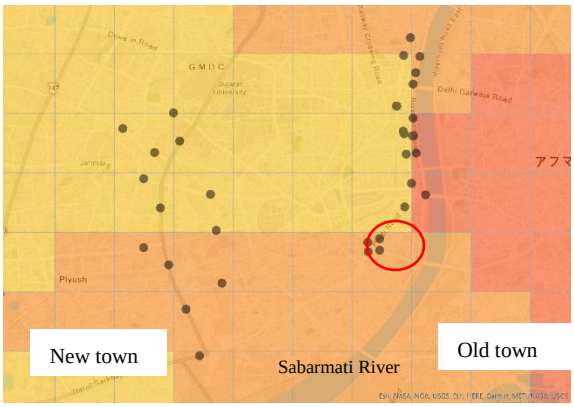


Figure 2: 1-Kilometer mesh with areal interpolation population and traffic monitoring camera location (red circle shows Paldi junction location and black dot marks are traffic monitoring camera position) .

2.2 Paldi Junction

In Figure 3, it shows more detail location for traffic monitoring cameras at Paldi junction.

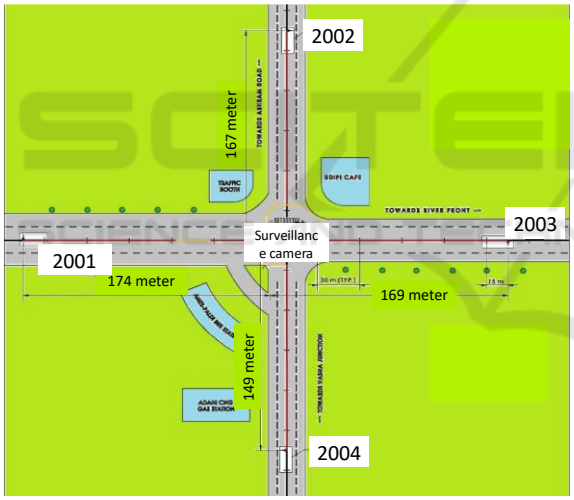


Figure 3: There are four traffic monitoring cameras and each traffic monitoring camera face to the centre of the junction (Number shows traffic monitoring camera location).

Each traffic monitoring camera monitors the number of vehicles and average speed. For example, it measures its traffic flow data of the vehicles which come from North to the junction at Camera 2004. At the centre of Paldi junction, there is a Surveillance camera which can take high definition visual condition and is remote controlled 360 degree. In Figure 4, traffic monitoring camera and Surveillant camera pictures are shown.

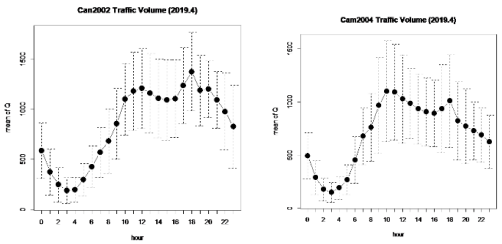
Figure 4: Traffic monitoring camera (left picture) and Surveillant camera (right picture).

3 MESUREMENT & ANALYSIS

In this section, it shows actual traffic measurement data and analysis at Paldi junction as Step 1. The traffic data is collected by four traffic monitoring cameras during April 2019 as an example data from eight months monitoring. As for comparison reference, another hourly measurement data is shown in Appendix later (traffic volume and average vehicle speed in January 2019. The trend of traffic volume is similar with that in April).

3.1 Traffic Flow Data

As Step2, it focuses on the traffic flow especially from North to South which is measured by Camera 2002 and 2004 as mention in the previous assumption. The camera 2001 and 2002 data are shown in Appendix. At first, Figure 5 shows the time-based traffic volume at camera 2002 and 2004. The traffic volume is one of traffic flow parameter and it is defined as number of passing vehicle on the road per hour.

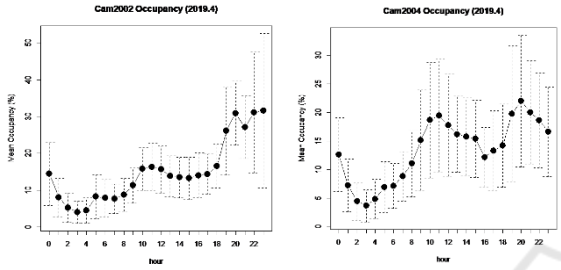


(a) Traffic Volume at 2002 (b) Traffic Volume at 2004

Figure 5: Traffic Volume at camera 2002 and 2004.

From Figure 5, traffic volume peak point is contrary relevant in the morning 10:00 and evening 18:00. In the morning, many vehicles go from North to South for their business, then the traffic volume at 2004 is larger than that of 2002. In the evening, it supposes majority vehicles direction between 2002 and 2004 is changed because of returning home.

In terms of traffic congestion, traffic occupancy is capable to indicate its congestion rather than traffic volume from previous study. In Figure 6, the occupancy is shown.



(a) Occupancy at 2002 (b) Occupancy at 2004

Figure 6: Occupancy at camera 2002 and 2004.

As Step 3, it introduces the occupancy (*OC*) which is also one of traffic flow parameter to analyse quantitative traffic congestion. This is defined as vehicle occupation percentage of road. (*OC*) is calculated from traffic volume (*q*) and average vehicle speed (*v*) by Equation (1) from traffic flow theory.

$$OC = 100 \times \frac{q}{v} \times \bar{l} \qquad (\%) \qquad (1)$$

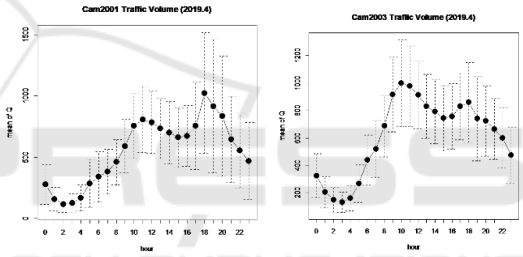
where (*q*) is traffic volume, (*v*) is average vehicle speed, and $\bar{l}$ is average vehicle length.

When it is compared between traffic volume trend of Figure 5 and occupancy trend of Figure 6, traffic volume does not always show its traffic congestion. For example, from traffic monitoring camera 2004, the highest peak of traffic volume occurs at 10:00, but congested peak by occupancy occurs at 20:00. From traffic monitoring experience, heavy traffic congestion occurs over 20% occupancy. Therefore, in case of traffic monitoring camera 2002, the traffic volume in the morning is high but occupancy level is less than 20%. This case is North and South traffic movement. In terms of traffic flow direction, each traffic monitoring camera faces towards the centre of the junction. The traffic monitoring camera 2002 faces to the South and camera 2004 faces to the North. Therefore, in the morning, the traffic volume from North to South which means traffic volume of camera 2004 is higher than that of camera 2002. So, majority of traffic flow moves from North to South. On the other hand, the traffic volume from South to North in the evening which means traffic volume of camera 2002 is higher than that of camera 2004. Majority of traffic flow moves from South to North. The traffic congestion occurs at 20:00.

From Figure 6, the evening traffic congestion occurs at 20:00. But from Figure 5, the evening traffic volume becomes peak at 18:00. There is two hours "Gap" between each peak of occupancy and traffic volume somehow. This "Gap" comes from the balance between traffic volume and average vehicle speed from Equation (1). This point is discussed in the next section.

At the end of section, let's check traffic flow from east to west, which is based on measurement data from traffic monitoring Camera No.2001 and 2003.

The traffic volume of both traffic monitoring Camera 2001 and 2003 is shown in Figure 7.



(a) Traffic volume at 2001 (b) Traffic volume at 2003

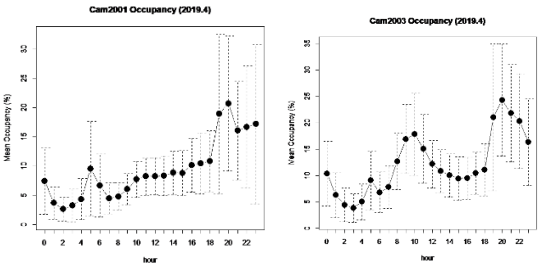
Figure 7: Traffic volume at camera 2001 and 2003.

From east-west traffic volume observation in Figure 7,

- People movement from West to East in the morning
- People movement from East to West in the evening

In terms of occupancy at camera 2001 and 2003, it shows hourly occupancy trend in Figure 8.

(a) Traffic Volume at 2001 (b) Traffic Volume at 2003



(a) Occupancy at 2001 (b) Occupancy at 2003

Figure 8: Traffic Occupancy at Camera 2001 and 2003.

In this case, traffic congestion occurs at 20:00 in both location. Here is congestion "Gap" between traffic volume and occupancy again.

As Step 4 when it focuses on traffic congestion of Paldi junction at 20:00, the three-dimensional occupancy condition in Figure 9 provides its traffic congestion image. In case of North and South, there is heavy congestion in North. In case of East and West, there are light congestions in both side. In Figure 10, two GIS map at 10:00 and 20:00 in 26th of April are shown as an example of traffic congestion situation.

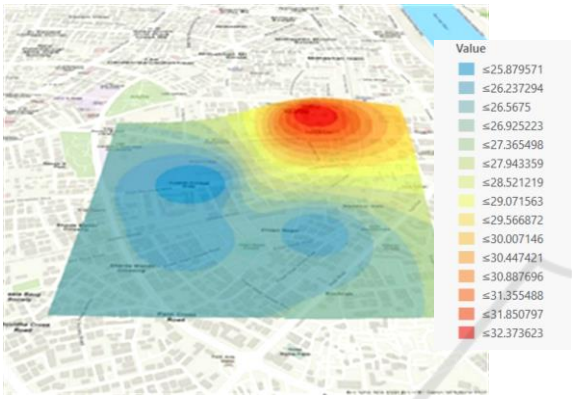


Figure 9: Occupancy at Paldi junction in April 2019 20:00 (value shows the level of occupancy).

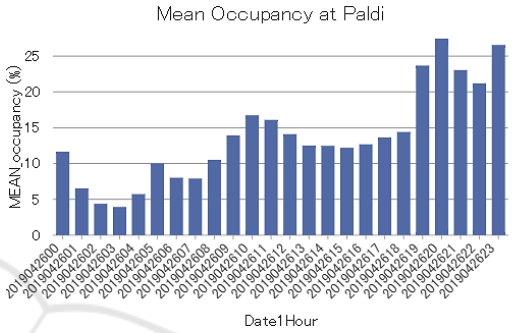
(a) Paldi junction occupancy at 10:00

(b) Paldi junction occupancy at 20:00

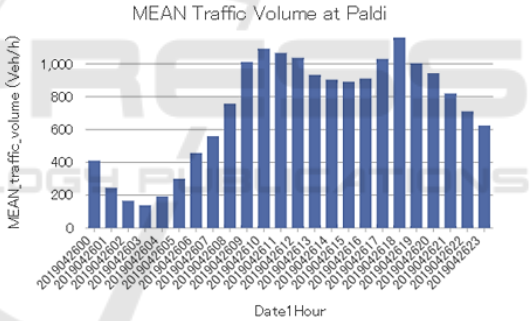
Figure 10: Occupancy at Paldi junction in 26th of April. From Figure 9, it is clear that traffic congestion location is different—south area in the morning and north area in the evening.

3.2 Congestion Analysis

In the previous section, occupancy is one of appropriate parameter for showing traffic congestion. When we investigate the relationship between traffic volume and occupancy from measurement, it shows the summary of traffic volume and occupancy among four traffic monitoring measurement on 26th of April 2019 in Figure 11. The number of traffic volume is average among four traffic monitoring cameras and its data unit is unified number of vehicles per hour per lane.



(a) Traffic Volume at Paldi junction



(b) Occupancy at Paldi junction

Figure 11: Comparison between Traffic Volume and Occupancy at Paldi junction on 26th of April 2019.

As mentioned earlier, there is congestion "Gap" between traffic volume and occupancy peak. The traffic volume peak occurs at 10:00 and 18:00 and the Occupancy peak at 10:00 and 20:00. Time "Gap" between traffic volume and occupancy in the evening is two hours.

From this analysis result, traffic congestion is not always happed under heavy traffic volume and there must be some other reason behind. If heavy traffic volume creates congestion, it should be happened in the morning. But based on one-month traffic flow observation, there is no traffic congestion in the morning. And another important fact is why traffic congestion "Gap" occurs in the evening, NOT in the morning. These two points are decried in the next Discussion section.

4 DISCUSSION

Let's take one moment for traffic volume trend at Paldi junction again. In Figure 12, it shows total four traffic monitoring cameras time-based traffic volume change in April 2019.

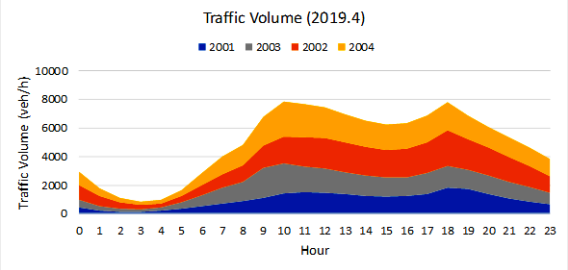


Figure 12: Accumulated Traffic Volume time-based change at Paldi junction.

There are two peaks of traffic volume at 10:00 and 18:00. In case of occupancy, it shows total four traffic monitoring cameras time-based traffic volume change in April 2019 in Figure 13.

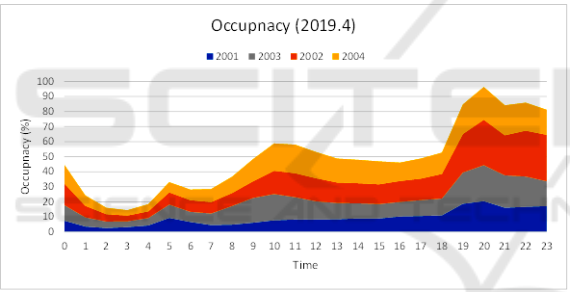


Figure 13: Accumulated Occupancy time-based change at Paldi junction. From Figure 12, there are two peaks of occupancy at 10:00 and 20:00. It is clear that there is congestion "Gap" between traffic volume and occupancy.

Table 2: Summary of Traffic Congestion "Gap".

Cam No.	Congestion time		*q* max time		Congestion "Gap" (hours)	
	AM	PM	AM	PM	AM	PM
2001	—	20:00	10:00	18:00	—	2
2002	10:00	20:00	12:00	18:00	0	2
2003	10:00	20:00	10:00	18:00	0	2
2004	11:00	20:00	11:00	18:00	0	2

Table 2 summaries comparison between congestion peek time from occupancy and traffic volume peek time from traffic volume. There is two hours congestion "Gap" of all location at Paldi junction. In case of camera 2001, occupancy peek in the morning occurs at 5:00. This situation comes from no congestion of camera 2001 at 10:00 from Figure 13. Other camera 2002, 2003, and 2004 have third peek of occupancy at 5:00 as well.

The Paldi junction environment is shown in Figure 14 as an example of snapshot. In the junction, there are traffic signal lights at each corner. And the traffic signal control is used round lobbing access with fixed time interval. There are several fixed time interval selections and it is selected depend on its traffic flow condition. This is typical Indian traffic signal control method and it is necessary to have detail traffic flow analysis related with traffic signal control system in future.

Figure 14: Example Paldi junction traffic condition.

From the above all traffic flow measurement observation long term and traffic flow analysis, it is not clear why traffic congestion occurs in the evening, NOT in the morning. We have several local traffic officer's discussions about Ahmedabad traffic congestion issues and we found one of congestion reason was transport behaviour as follows:

- Residents go straight to their office in the morning by own private vehicles and then they park their vehicle at certain regular parking space.
- Some residents return straight to their home after work but some go to shopping and or restaurants for dinner in the evening. And there is some difficulty to find parking space. In general, there are not so many appropriate parking area in India. Some people park along the street when they are lucky to find the space. If not, some people park their vehicles not allowance space on the street, which makes narrow the road width eventually.
- Local police officer does some time control its traffic by manual because the fixed time interval control does not effectively work for traffic congestion, especially in the evening.

In order to find out the reason for daily traffic congestion in Ahmedabad, it is not only to have more data but also check actual traffic condition time and day such as investigation at 20:00 weekday. It is also worth to have workshop among road management group including traffic police and interviews to residents. We also have other traffic monitoring cameras s under the project and continue this traffic management research by March 2022. As mentioned earlier, the first city Metro is under development in Ahmedabad and it will help to provide more appropriate transportation choice to residents in near future.

ACKNOWLEDGEMENTS

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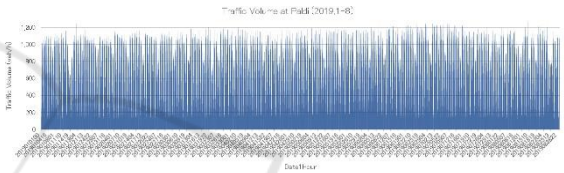
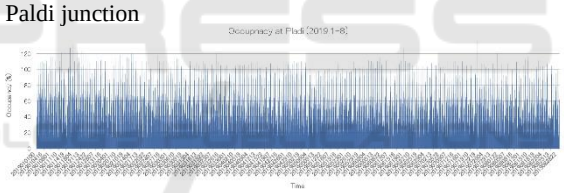
APPENDIX

Here is a reference data of traffic volume and occupancy during 8 months from January to August 2019 in Figure A. The characteristics of traffic volume and occupancy is based on all four traffic monitoring camera and its value is used as average data. Each characteristics are same trend by each month, day, and time. Therefore, the analysis result which is described in this paper is same result even if it is taken other month or day.



(a) Traffic Volume trend during January to August 2019 at Paldi junction



(b) Occupancy trend during January to August 2019 at Paldi junction

Figure A: Long term Q and OC trend at Paldi junction.