Development of Road Congestion Index Based on Comprehensive Parameters

Geetanjali Chandam, Yanchen Oinam, Rochitra Keisham, N. Nungdren, Pratheeba Paul

Abstract: Traffic congestion is a normal phenomenon associated with transportation on the road at the same time which is hinder motion and need extra time to reach destinations. Congestion is one of the problems involving road. Normally, network congestion occurs on land transport on roads. As demand approaches the capacity of a road or of the intersection along the road, extreme traffic congestion will set in. When vehicles are fully stopped for periods of time, this is colloquially known as a traffic jam or snarl-up. Traffic congestion can lead to drivers becoming frustrated and engaging in road rage. In this study of developing congestion index for heterogeneous traffic at the road stretch from Navalur to Kelambakkam and Kelambakkam to Navalur, the study initially focuses on the identification of factors affecting traffic congestion, and finding the most feasible location for congestion by developing a congestion index based on speed and saturation degree, with these two important approach solution of each area is suggested. To calculate the traffic congestion index, a thorough literature review has been conducted and all the possible parameters are identified. A questionnaire was prepared with relevant factors affecting congestion and distributed to the people, who are resident or frequent users. The most significant factors are considered for further study to avoid congestion. Lack of number of lanes, no pedestrian pathway, on road parking, location of toll were found to be the most affecting factors, so we suggest widening of roads, effective parking system, etc. It is also observed that particular area of Padur and Kelambakkam were the main concern of traffic congestion. This is confirmed both practically and theoretically with the help of the survey and the congestion index values.

Keywords: Traffic congestion, road, congestion index, saturation degree, Pareto chart.

I. INTRODUCTION

A. Road Congestion Index

The measure of vehicle travel density on major roadways in urban area is called road congestion index. If RCI exceeds 1.0 it indicates an unacceptable congestion level, on an average, on the freeways and major arterial street during peak hours. The detection and analysis on traffic congestion index can be used to estimate the operation status of roads, to plan and organize road traffic for traffic management, and to make the reasonable decisions of travelers to travel. Congestion is the inability to move (immobility). Congestion is a phenomenon in which long lines of vehicles moving slowly or stopped at the highway city, suburban highways or city streets. Congestion can occur every day at the same time at a specific location that is referred to as recurrent congestion or accidents during road maintenance or availability of any non-recurring congestion. Normally, congestion occurs when the road system cannot accommodate the volume of traffic at a reasonable speed, there is a conflict between the various types of traffic such as cars, trucks, buses or pedestrians and traffic control are not used efficiently. Convergence path, decreasing the capacity of a sudden, that movement is stuck or increased friction also led to increased traffic congestion.

B. Need for study

Traffic congestion during peak hours is a daily problem in the particular road stretch we have chosen for study in this case. Since there are many high rise apartments, educational institutions, IT companies and ongoing new constructions on the road stretch, there is an unavoidable congestion during the peak hours especially during morning hours and evening hours. Traffic congestion causes interruption to the flow of traffic and instantly affects the society in many ways. We have made an attempt in this study to bring out solutions for this societal problem. The road stretch from Navalur to Kelambakkam which is approximately around 8 kilometer which is located along Old Mahabalipuram Road is considered for our study.

- Navalur is a rapidly growing southern suburban of Chennai and the area was once a village (around 2010) but with the advent of IT companies and the rapid development of the Old Mahabalipuram Road, it has become a bustling and most demanded location in Chennai.
- Padur, the rapidly developing part of OMR also positioned between Navalur and Kelambakkam. Padur was known for its commercial growth but, now it is entering into its prime with increasing job openings and residential development into the urban living as well.
- Kelambakkam is a suburban and residential neighborhood. It is located in the south-eastern portion of the city along the OMR and is about 5 km from Siruseri IT Park. It is another important junction after Sholinganalur, which connects GST road and ECR road.

II. METHODOLOGY

The first step involves conducting the video graphic traffic volume survey. The data collection was carried out on Monday and Friday at three locations – Navalur near toll gate (L1), Kelambakkam near junction (L2) and Padur near Bus stop (L3). The data is collected for both the directions of road classified as – towards North (R1), towards South as (R2), for two timings – Morning (8-10) as (T1) and Evening (5-7) as (T2).
The table below shows the traffic volume data for Monday and Friday:

**Table 1. Traffic Volume Data**

| Node, Road Timing | Peak Hour Volume (PCU) Monday | Peak Hour Volume (PCU) Friday |
|-------------------|-------------------------------|-------------------------------|
| 111               | 2561                          | 2531                          |
| 211               | 1670                          | 1771                          |
| 311               | 2010                          | 1894                          |
| 121               | 4259                          | 4225                          |
| 221               | 2212                          | 2321                          |
| 321               | 1828                          | 2411                          |
| 112               | 2421                          | 3821                          |
| 212               | 1446                          | 1568                          |
| 312               | 1576                          | 1724                          |
| 122               | 1990                          | 2361                          |
| 222               | 1855                          | 1899                          |
| 322               | 2063                          | 2301                          |

A questionnaire survey has been prepared with relevant factors affecting congestion and conducted the survey. The questionnaire was prepared and the views of the road stretch were collected from the road users and analyzed for finding out the significant factors. Some of the relevant factors considered and the data collected are given in the table below:

**Table 2. Questionnaire Survey Data**

| Causes of traffic congestion | Points | Cumm. | Cumm. % |
|------------------------------|--------|-------|---------|
| Lack of pedestrian pathways  | 98     | 98    | 9.29    |
| On road parking              | 96     | 194   | 19.4    |
| Lack of no. of lanes         | 94     | 288   | 28.8    |
| Private public transport     | 93     | 381   | 38      |
| Location of toll             | 91     | 472   | 47.1    |
| Heavy motor vehicle          | 90     | 562   | 56.1    |
| Delay due to traffic volume  | 89     | 740   | 73.9    |
| Bad road condition           | 89     | 740   | 73.9    |
| Accidents                    | 41     | 781   | 78      |
| Festival and seasonal factors| 40     | 821   | 82      |
| Not following traffic rules  | 39     | 860   | 85.9    |

From the analysis of questionnaire survey, a pareto chart is created. Pareto analysis is a statistical technique in decision in decision making used for the selection of a limited number of tasks that produce significant overall effect. It uses the Pareto Principal (also known as the 80/20 rule) the idea that by doing 20% of the work you can generate 80% of the benefit of doing the entire job.

**Table 3. Pareto Analysis**

| Causes of traffic congestion | Points | Cumm. | Cumm. % |
|------------------------------|--------|-------|---------|
| OFFICE, COLLEGE              |        |       |         |
| DUE TO RESIDENTIAL APARTMENTS| 20     |       |         |
| RECREATIONAL FACILITIES      | 11     |       |         |
| LACK OF PEDESTRIAN PATHWAYS  | 98     |       |         |
| HEAVY MOTOR VEHICLE MOVEMENT | 90     |       |         |
| PRIVATE GOODS TRANSPORT VEHICLE| 28    |       |         |
| PRIVATE PUBLIC TRANSPORT     | 93     |       |         |
| ACCIDENTS                    | 41     |       |         |
| MISSING SIGN BOARDS          | 15     |       |         |
III. CALCULATION OF CONGESTION INDEX

A. Congestion Index Based On Speed

Actual speed of the road has to be found out in order to find congestion index based on speed. The distance travelled by the vehicle is noted and the time taken is found out then Actual speed is found out for the road stretch using the formula

\[
\text{Speed} = \frac{\text{Distance}}{\text{Time in Kmph}}
\]

The Congestion Index is calculated using a collected data with the following formula:

\[
CI_{LRT} = \frac{(V_{LRT} - V_{LRT}^r)}{V_{LRT}^r} \times 100
\]

\(CI_{LRT} = \) Congestion Index; \(L = \) Location; \(R = \) Road; \(T = \) Timing; \(V_{LRT}^r = \) Acceptable speed (based on IRC); \(V_{LRT} = \) Actual speed; If \(V_{LRT} < V_{LRT}^r\) Congestion Index = 0
Free flow

| Node, Road, Timing | Congestion Index (Monday) | Congestion Index (Friday) |
|--------------------|---------------------------|---------------------------|
| 111                | 34.9%                     | 40.4%                     |
| 211                | 48%                       | 42.4%                     |

B. Congestion Index Based On Saturation Degree

The designed capacity is 1450 veh/h for one lane (as per IRC) with design speed 45kmph. The extent of congestion will increase when saturation degree enlarge. Saturation degree can be divided into six stages and road congestion index can be calculated in the range of 2 – 10. (1)

Saturation Degree, \(x = \frac{\text{Volume}}{\text{Capacity}}\)

To calculate the Congestion Index, we have to find the value of saturation degree(x) with the help of traffic volume data from Table1 and the value of capacity as per IRC. With the saturation degree obtained we can calculate the congestion index using the formula below

\[
CI_{LRT} = \begin{cases} 
0 & x < 0.4 \\
\frac{x - 0.4}{0.2} \times 2 + 2, & 0.4 < x < 0.6 \\
\frac{x - 0.6}{0.15} \times 2 + 4, & 0.6 < x < 0.75 \\
\frac{x - 0.75}{0.15} \times 2 + 6, & 0.75 < x < 0.9 \\
\frac{x - 0.9}{0.2} \times 2 + 8, & x > 1 
\end{cases}
\]

| Node, Road, Timing | Congestion Index (Monday) | Congestion Index (Friday) |
|--------------------|---------------------------|---------------------------|
| 111                | 27%                       | 27%                       |
| 211                | 38%                       | 41.3%                     |
| 311                | 50%                       | 46%                       |
| 121                | 65.3%                     | 65.3%                     |
| 221                | 66%                       | 66.7%                     |
| 321                | 64%                       | 70.6%                     |
| 112                | 25%                       | 32%                       |
Development of Road Congestion Index Based on Comprehensive Parameters

| 212  | 30%  | 34%  |
|------|------|------|
| 312  | 34%  | 39%  |
| 122  | 18.5%| 24%  |
| 222  | 45.3%| 45%  |
| 322  | 45.3%| 65.3%|

IV. DISCUSSION AND SOLUTIONS

From the above congestion index based on speed and saturation degree, 6 most congested location, road and timing is found out from each cases. From there we can see 4 repeated significant congestion level in Navalur road 2 from 8-10 am, 8 in Padur road 1 and 2 from 8-10 am, 3 in Padur road 2 from 5-7pm, 1 in Padur road 1 from 5-7pm 4 in Kelambakkam road 2 from 8-10am, 1 in Kelambakkam road 1 from 8-10am, 4 in Kelambakkam road 1 from 5-7pm, 1 in Kelambakkam road 1 from 5-7pm.

SOLUTIONS:
From the survey and Pareto chart the most significant factors are found, the solution of each factor is studied with the help of various research papers and each way for avoiding the causes of traffic congestion is suggested as follows:

- **LACK OF PEDESTRIANS PATHWAY**

Existing road width of Padur is 5.73m on both sides with 1.74m for both parking and walkways but sometimes this is also being blocked by roadside vendors or it is being occupied by the road users during heavy traffic and also a carriage way of 4.2m.

Fig 2. Pedestrian packed on the carriageway

Widening of 1.5m width shoulders on both sides for 1.2km is necessary to ease traffic congestion as this particular stretch is the most strained location in the study area. Pedestrian footpath for at least 1.5m is suggested as per IRC Guidelines, pedestrian road width are shown for commercial and residential zones in the figure below along with this restriction of street vending in certain congested area.

Fig 3. Pedestrian pathway for residential zone

- **ON STREET PARKING**

Properly planned and managed on street parking is necessary for smooth flow of traffic, proper lane markings, allocation of parking space. Parallel parking is suggested as they offer much less disruption to the moving traffic but parking and un-parking might be challenging. The figure below shows different types of parking along with the parking width where parallel parking occupies a road width of 2m.

Fig 5. Types of parking

- **LACK OF NO. OF LANES**

Lack of no. of lanes can be seen in two particular location of the study area i.e. Padur and Kelambakkam whereas the lanes in the Navalur area is wide enough but the road users violating the road rules is the major factor of traffic congestion.

Widening is another solution suggested which will allocate vehicle parking and pedestrian footpath, thereby, allocating sufficient road width and no disruption in the carriageway. Widening need not be implemented for the whole study area of 8 km, for an economical approach we can implement it in the Padur locality for about 1.2km where most of the street vendors, bus stops and Hindustan Institute of Technology and Science is located and another 1.5 km at Kelambakkam located between two main junctions i.e. Kelambakkam-Vandalur junction and Kelambakkam-ECR junction.

Fig 6. Existing Road width (red) and widened area (green)

The below figure shows the aerial view of Padur and the no. of U-turns allowed in a distance of 1.2Km, the road width in Padur area is 4.2m on each direction with a shoulder width of 1.5m and in some particular area the roads are even narrower due to encroachment by the street vendor.
There is a U-turn at Hindustan university and there are 4 U-turn roads at about 350m, 160m, 140m, 60m, 210m respectively due to this behavior the roads are frequently blocked, the location of bus stop and u turn area overlapped which leads to increase in the road congestion during peak hours.

**PRIVATE-PUBLIC TRANSPORT**

Due to the specific locations of many IT companies, there is a high demand for public private transport in this stretch. More than thousands private public transport uses the road being a major concern for the road congestion causes. Some of the examples of private-public transport are auto, mini-van, mini-bus, etc.

Specific stops – As like state owned public transport if specifics can be assigned for private transport to avoid sudden stops which is the cause of many minor accidents. Continuous flow of such traffic should be encouraged, awareness sign boards can be installed to keep the road users well informed, strict rules should be imposed to stop the violation of traffic rules.

**LOCATION OF TOLL**

The tollgate on the Rajiv Gandhi Salai is a dreaded task; it takes a minimum of 30 minutes to cross the tollgate during rush hour. Because of this, many motorists take the wrong side of the road to avoid waiting.

**REFERENCES**

1. Huimin Wen, Jianping Sun, and Xi Zhang. “Study on Traffic Congestion Patterns of Large City in China: Taking Beijing as an Example”, Beijing Transportation Research Center. The 9th International Conference on Traffic & Transportation Studies (ICTTS’2014).
2. Wanxiang Wang, Rui-jun Guo and Jing Yu, School of Transportation Engineering, Dalian Jiaotong University, Dalian. “Research on road traffic congestion index based on comprehensive parameters: Taking Dalian city as an example”. Issue published: June 1, 2018
3. Amudapuram Mohan Rao and Kalaga Ramachandra Rao, “Measuring Urban Traffic Congestion – A Review”, Indian Institute of Technology Delhi, Department of Civil Engineering, Hauz Khas, New Delhi; International Journal for Traffic and Transport Engineering, 2012.
4. Zhao, Pengjun and Hu, Haoyu. (2019). Geographical patterns of traffic congestion in growing megacities: Big data analytics from Beijing.
5. Shekhar K. Rahane and Prof. U. R. Saharkar, “Traffic Congestion - Causes and Solutions: A Study of Talegan - Dablihade City”. Journal of Information, Knowledge and Research in Civil Engineering. ISSN: 0975–6744 | NOV 13 TO OCT 14 | Volume 3, Issue 1.
6. Syed Sabreen and Paramjeet, Civil Engineering Department, Geeta Engineering College, Naultha, Panipat. “Analysis of Traffic Congestion in Srinagar City - A Review”. September 2018 USDR | Volume 3, Issue 9.

**AUTHORS PROFILE**

Geetanjali Chandam, is a student of Hindustan Institute of Technology and Science, she will be completing her Bachelor’s degree in May 2020. She is highly interested in gaining practical knowledge where she joins project and research works. She was selected for an Indo – German traffic Project where she accomplished a big part of the project. She has been awarded the Best Project Award for her contribution.

Yanchen Oinam, is a student from the Dept. Of Civil Engineering, Hindustan Institute of Technology and Science. He is a campus ambassador of Civil Engineering Association, IIT Madras. He has completed an Internship Program under AIESEC organisation in Cairo, Egypt. He also published a book of poems; his book is available on online retailing stores like Amazon. He has been awarded the Best Student Award for his contribution and hard work.
Development of Road Congestion Index Based on Comprehensive Parameters

Rochitra Keisham, is a student of Hindustan Institute of Technology and Science. She has completed her Bachelor’s degree on May, 2020. She has also completed an internship program under Superintendent of police housing co-operation limited.

N Nungdren, is a student of Hindustan Institute of Technology and Science. He has completed his Bachelor’s degree on May, 2020. He has also completed an internship program under Superintendent of police housing co-operation limited.

Dr. Pratheeba Paul, is a professor at Hindustan Institute of Technology and Science. She has a teaching experience of 24 years. She has published around 30 papers in Journals and Conferences. She has received a best Researcher award from IJRULA in 2018.