Analysis of Traffic Congestion Impacts of Urban Road Network under Indian Condition

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Abstract. Traffic congestion has been an area of major bother across the globe. The existing infrastructure is not able to cope with the new traffic demand. Furthermore the restriction of the space and outside activities influencing the traffic congestion. The emerging country like India, where the traffic conditions comprise heterogeneous traffic with no lane discipline, further creates more complicated scenarios for the researcher. A substantial portion of working hours is getting wasted on the roads because of traffic congestion, which imposes the negative effect on the overall economy. There has been numerous of literature and studies for analysis of the traffic congestion and its impacts. However, the result has not been much satisfying. In the present study congestion forecast is aimed under mixed traffic with no lane discipline towards identifying the inherent viability of the diversified traffic situation and presents better recommendations in controlling and evading these prolonged traffic jams. The urban highway systems were considered as a study area. Required particulars were collected by a License Plate Matching method using video graphic survey for the day rush timing considered from 8:00 AM to 10:00 AM and off peak hours to estimate the travel time of a distinct class of motorized vehicles for selected sections of the urban roadway. Congestion indices for both the up and down traffic of a particular road were evaluated from the data collected from the video recording. Traffic congestion impacts were analyzed and possible mitigation measures have been suggested. The study mainly focused on traffic jam indices with regarded to travel time reliability measures to observe the functional effectiveness of the urban road network.

1. Introduction

Congested traffic, leads a significant threat that hinders the growth of a country. Due to the growth in population and motorized vehicles, there is huge congestion on the roadway. Increasing population and vehicles, the transhumance of rural inhabitants to metropolitan cities hunting for superior opportunities are the fundamental reason of the traffic jam. Traffic Congestion may be categorized into two types, i.e. recurring type, which is primarily taken place due to capacity and behavioral issues or non-recurring type, which is because of accidents, construction, or emergencies. The recurring and non recurring congestion, having different causes, but having indistinguishable effects. Traffic jam accelerates additional hindrance, causing the unpredictability to traveler engendering to personage tension and risky transportation circumstances. Defective traffic signaling structures, scarcity of the workforce, limited roadway width and overtaking
proneness of motorists extended the road congestion. The valuable working hours of the road users getting wasted on the road, which secondarily adversely influenced the overall economy. Traffic congestion not only affecting the human being, but also elevates the pollution.

Traffic congestion also influences accessibility and mobility. Traffic congestion increases travel time and fuel costs, which adversely effecting organizations and employees distributing goods and services. Traffic congestion is normally described as the traffic demand surpassing the roadway capacity. Traffic density (the number of vehicles in a specified length of a roadway) is one of the most frequently used congestion indicators. The travel time reliability measures such as level of service, roadway congestion index and lane-mile duration index can also be considered to identify the traffic congestion parameters. For evaluating the traffic congestion in the urban roadway, the speed performance index is one of the indicators. There is extensive mental as well as physical stress on drivers because of traffic congestion and increases their aggression which might induce unfortunate incidents like road crashes. Every day by millions of people across the globe are directly affected by the traffic congestion. Traffic congestion originates significant air pollution and noise pollution consequently aggravate the whole atmosphere surrounding. Congestion pricing techniques as a measure of congestion mitigation have been suggested by the majority of the researcher. The impact of traffic congestion can be related to Fuel expenditure cost, Transit cost, Health associated matters and Environment concerned matter.

The current traffic framework is inadequate to encounter the traffic demand due to an exponential increase in population as well vehicle. This research aims to analyze the traffic congestion impacts of the urban road network of a smart city in India. Congestion indices have been evaluated to examine the operational efficiency of the road network. In order to plan the trips productively and to choose the routes suitable travel time reliability measure has a significant part to the travelers. Finally, the study also examines the traffic congestion impacts and its mitigation measures.

2. Literature review
Qingyu et al. (2007) analyzed qualitative and quantitative of the external costs that the urban traffic congestion pricing. Described the external costs of traffic congestion in terms of extra travel time costs, environmental pollution costs, traffic accident costs, and fuel consumption costs. Lyman, and Bertini (2008) described congestion measures and travel time reliability measures. Discussed different travel time reliability measures, but considered the buffer index as important measures. They suggested that adding travel time reliability measure can be a superior comprehension for the transportation network.

Padiath et al. (2009) illustrated the traffic congestion indicator in terms of traffic density. In order to establish the practicality, few approaches for density forecast under similar traffic circumstances are tired under the mixed traffic scenario. Uddin (2009) addressed the issues of increasing population and vehicles, especially passenger cars with some statistics. He also found that vehicles in India are distributed unevenly He identified that the transhumance of rural inhabitants to metropolitan cities hunting for superior opportunities is the one of the primary reasons of the urban traffic congestion. Zhili et al. (2009) forecasted the significance of congestion charge as per the locality, land use attributes, and present travel environment. Evaluated the travel situations under congestion pricing depends on travel demand model and given recommendations for executing the congestion charge. McGroarty (2010) focused on causes of recurring congestion, which is mainly occurring due to capacity and behavioural issues and non-recurring congestion, which is primarily occurring due to events which creates unanticipated congestion. Though the occurrences are different, but the impacts are similar.

Mahmud et al. (2012) found that restricted resources invested in the growth of transportation infrastructure, a quick jump up in transport demand, the intervenes of enormous non-motorized
vehicles on roads, lack of implementation of appropriate and realistic traffic governance strategy are the critical transport issues in almost all the urban areas.

Rao, and Rao (2012) focused mostly on urban arterial congestion. The study executed based on measurement metrics such as speed, travel time/delay and volume and level of service. They have adopted the travel time reliability measures to identify the traffic congestion parameters.

Dubey, & Borkar (2015) focused on detection techniques of the traffic congestion. They have described the major problem incurred during the detection of the traffic congestion on the urban road network. They have suggested to adopt GPS based technique for the betterment of the result in accordance with the traffic safety.

He et al. (2016) have adopted performance index to determine the existing road network conditions of congestion in urban road networks. For evaluation of traffic congestion, they have adopted the speed performance index as the evaluation indicator of urban road traffic system.

Samal, and Das (2020) have taken the buffer index to predict the congestion level in the specified road network. They have established regression modelling to see the differences in observed value and predicted value. Some of the recommendations have been suggested.

3. Data collection and analysis

3.1 Travel time estimation
Utilizing the common analytical methods or by application of computer software mean travel times are evaluated from independent travel times. The time indispensable to travel a path connecting any two points of interest called as travel time. For a comparatively short span travel time can be determined by accepting that the mean speed at a specific point (spot speed) is constant. The acceptance of steady speed over a brief roadway portion is relevant to continuous flow provisions with stable flow traffic pattern. For measurement of congestion indices travel time is in important parameter.

3.2 Travel time reliability
The measure of travel time reliability is the replacement of the volume-to-capacity proportion. It assists to govern the acceptability of the assistance furnished by the urban network The V/O ratio concentrates especially to construct additional roadways to accommodate the traffic demand, whereas travel time reliability measures are concentrated regarding superior administration of the current structure.

3.3 License plate matching techniques
It is one type of travel time data collection technique. Registration number matching approaches comprise of gathering vehicle registration number and entry time at different points, complementing the registration number between successive points, and determining travel times through the differences in entry times.

Four fundamental techniques are employed for gathering the information's about registration number matching approaches.

- **Physical Method:** With the help of conventional pen and paper or tape recorder gathering the information's about registration number and physically extracting the required data.
- **Portable Computer:** Gathering the information's about registration number in the working areas by utilizing movable computers that voluntarily extract the required data.
- **Video graphic technique with Physical Method:** By making use of video cameras gathering the information's about registration number in the working areas and physically extracting the required data.
- **Video graphic technique accompanied by Character Identification:** Gathering the information's about registration number in the working areas by video graphic technique.
and voluntarily extracts the required data by utilizing computerized registration number character identification.

The present study employed the Video graphic technique with Physical Method, i.e. by utilizing video cameras gathering the information’s about registration number in the working areas and physically extracting the required data.

3.4 Congestion indices

To evaluate the serviceability and overall performance of the present urban roadway, congestion indices are the significant variables. Congestion indices are the estimate of road network serviceability and overall performance. Different congestion indices are

- Travel Time Index (TTI)
- Buffer Index (BTI)
- Planning Time Index (PTI)

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Travel \ Time \ Index = \frac{Mean \ Travel \ time}{Off \ peak \ travel \ time}
\]

\[
Buffer \ Time \ Index = \frac{95th \ percentile \ travel \ time - Mean \ Travel \ time}{Mean \ travel \ time}
\]

\[
Planning \ Time \ Index = \frac{95th \ percentile \ travel \ time}{Off \ peak \ travel \ time}
\]

The present study has adopted Buffer Time Index to evaluate the congestion index for the selected urban road networks. BTI represents the traveler need to put additional time in their mean travel time to make sure on time arrival most of the time.

3.5 Selection of the study area

One of the significant and the first step of the research work is the selection of the study area. The location of study area decides the requirement of research activities to be done in consideration of the existing transport framework, traffic behaviour and traveller information. The urban road network has been taken as the study area for the evaluation of congestion indices.

**Table 1: Lane attributes of the chosen roadway**

| Sequence No. | Category of road | Lane attribute       |
|--------------|------------------|----------------------|
| 1.           | Arterial         | 6 lane divided       |
| 2.           | Arterial         | 6 lane divided       |

The present study focused on the two locations, where different data's were collected. The traffic volume count was executed during morning rush hours (from 8.00 A.M.to 10.00 A.M) and morning off-peak hours (from 2.00 P.M. to 3.00 P.M.) employing video graphic survey in the chosen road locations. According to Indian Road Congress106 -1990, “Guidelines for Capacity of Urban roads in Plain areas”, the volume count is analyzed.
Table 2: Recommended Passenger Car Unit (PCU) factors for different category of vehicles in urban road networks

| Sequence number | Category of vehicles               | Equivalent PCU Factors | Percentage Composition of different Vehicles |
|-----------------|-----------------------------------|-------------------------|-----------------------------------------------|
|                 |                                   |                         | 5%                                            |
| 1               | Two wheeler, Motorcycle or Scooter | 0.5                     | 10% and above                                 |
| 2               | Passenger car, pick up van        | 1.0                     | 1.0                                           |
| 3               | Auto Rickshaws                    | 1.2                     | 2.0                                           |
| 4               | Light Commercial Vehicle          | 1.4                     | 2.0                                           |
| 5               | Truck or Bus                      | 2.2                     | 3.7                                           |
| 6               | Agricultural Tractor Trailer      | 4.0                     | 5.0                                           |
| 7               | Cycle                             | 0.4                     | 0.5                                           |
| 8               | Cycle Rickshaw                    | 1.5                     | 2.0                                           |
| 9               | Horse Drawn Vehicle               | 1.5                     | 2.0                                           |
| 10              | Hand cart                         | 2.0                     | 3.0                                           |

Table 3: Buffer Time Index (%) of the chosen urban roadway

| Road Number     | Direction | Peak average travel time (Sec) | 95th percentile travel time (Sec) | BUFFER TIME INDEX (%) |
|-----------------|-----------|--------------------------------|----------------------------------|-----------------------|
| Selected Road 1 | 1-2       | 12.70                          | 16.50                            | 30                    |
|                 | 2-1       | 13.10                          | 16.60                            | 27                    |
| Selected Road 2 | 1-2       | 15.10                          | 20.30                            | 35                    |
|                 | 2-1       | 14.20                          | 18.40                            | 30                    |

Among the different congestion indices, the present study mainly focused on the Buffer Time Index, which gives acceptable outcomes in the mixed traffic environment. According to the constitution of the vehicle and lane assignment, the travel time and congestion indices are varied. Smaller the Buffer Index, better the serviceability.
4. Impacts of traffic congestion

The impact of congestion can be studied in three ways, such as impact on economy, impact on the environment and impact on health. For the current research work the relevant information has been assembled from various activities, e.g. group conversation, questionnaire review, physical monitoring, individual Interaction, journals and articles, website articles, and preceding works on the relevant matter to study the impact of traffic congestion on various parameters.

4.1 Impact on economy

People are forced to wasting money in different methods due to traffic congestion, such as wasting man hour, additional transportation cost, additional fuel consumption, vehicle operating and maintenance cost and diverse cost. From the collected data the study found that travellers are wasting 50% of their traffic hourly during the journey, e.g. if the traveller requires 1 hour during off peak hours for the journey and the same length of the road will take 1.30 hours to the traveller during the peak hours. The extra time, which they can transform towards precious working hour that could contribute to the overall economy.

![Figure 1: Wastage of time due to traffic congestion](image1)

4.2 Impact on health

Because of congestion people are forced to spend extra time on the road, which directly affecting the health of the individuals. The impact of health due to congestion cannot be neglected. The data have been collected as mentioned sources to study the impact of congestion on health related issues. From the collected response we found that, 81% individuals are getting affected because of traffic congestion, Whereas 16% individuals gave a response that their health was not getting affected due to traffic congestion and 3% response did not have any conclusive answer.

![Figure 2: Percentage of people suffered due to traffic congestion](image2)
The study has categorized the symptoms of suffering in different ways, such as respiratory complication, neuralgia related difficulties, psychological distress, trouble in hearing, unpredicted sweating, fatigue, suffocation, dust allergy, difficulties in visibility, digestion problem, dehydration etc.

![Figure 3: Percentage of categorized symptoms suffered due to traffic congestion](image)

It can be seen that the majority of the suffering is related to breathing (20%), headache (18%), mental stress (16%) and sweating (15%), which can be considered as high level of distresses. Whereas hearing (8%), tiredness (10%) and dust allergy (6%) considered as a moderate level of distresses. Low level of distresses is suffocation (3%), Eye problem (3%) and others e.g. digestion problem, dehydration etc.

4.3 Impact on environment
The environment plays an important role in traffic congestion. The environment is getting polluted on the whole by sound pollution and air pollution. During the traffic congestion the roadway is of its full capacity. Everyone wants to be free from congestion. The sound created from vehicle as well as horns by the operator really creates the worst environment. Not only the people who suffer from traffic congestion, but also the neighbours people are also disrupted. When vehicles put a stop for a prolonged period of time on the road due to congestion, the gases like SO2, CO, CO2, NO2 emitted, which is lightweight compared to air yet too harmful. The impact of environment can be categorized in different aspects, e.g. disturbance due to the horns, disturbance due to noise pollution, irritation, ill temper, having problem with concentration and sleeping, trouble in hearing and honking of drivers in traffic congestions.

5. Suggested mitigation measures
The present study mainly focused on the improvement of the existing infrastructure which does not require any huge investment. The data collected from various sources, e.g. general people, experts, researchers, academicians, engineers, research article, etc.
### Table 4: Traffic congestion mitigation measures

| Activities                                         | Perception Percentages (%) |
|----------------------------------------------------|----------------------------|
| Awareness building                                 | 3                          |
| Construction of flyovers                           | 11                         |
| Public transportation uses                         | 7                          |
| Strict traffic law Implementation                  | 16                         |
| Rescheduling of Office/School timing               | 4                          |
| Subway                                             | 3                          |
| Removing Non Motorized Vehicle (NMV)               | 2                          |
| Decentralization                                   | 16                         |
| Controlling road side activities                   | 16                         |
| Car free days and discourage private cars          | 1                          |
| High Parking charge                                | 3                          |
| Increasing pedestrian facilities                   | 2                          |
| Adequate parking facilities                        | 16                         |

![Figure 4: Percentage of factors Suggested for the mitigation measures](image)

Figure 4: Percentage of factors Suggested for the mitigation measures

The present study tried to collect the information regarding the implementation of congestion mitigation techniques. New constructions are not given priority as the present study mainly focused on improvement of existing infrastructure. Very interesting facts are collected from the data as most of people are aware about the congestion, but they are not following the traffic rules. Majority of people gave a strong information about decentralization of government organization, Important sectors e.g hospitals, colleges, industries etc. From the most of the literature we observed that more importance given to Removing non motorized Vehicle (NMV), Car free days, High Parking charge, Increasing pedestrian facilities to counteract the congestion, where as in this study we have collected less response in this regards. The reason was the due to the increase of two wheeler the amount non motorized Vehicle (NMV) are getting absolute day by day. Even though there will be implementation of High Parking charge, Increasing pedestrian facilities, still without strict traffic law all of these factors cannot be implemented.

### 6. Conclusions and recommendations

Following conclusions can be drawn from the present study and analysis of traffic congestion data were collected from urban road networks in India and recommendations are also provided for the
mitigation regarding the traffic congestion in the studied area. According to the vehicle composition and lane distribution, there is the variation of travel time and congestion indices. Buffer Time Index displays adequate outcome in mixed traffic conditions among the other indices. Several factors were considered to assess the congestion indices as well as analyze the influence of traffic congestion on the overall economy, environment including health. Congestion cannot be eliminated totally due to the increase in population as well as vehicle, specially two wheelers and passenger cars. Among the suggested congestion mitigation measures, the majority of the people have suggested that the congestion can be minimized by Implementation of strict traffic law, decentralization of important organization, controlling road side activities and adequate parking facilities.

There has to be proper coordination between the expert/researcher those are involved in the planning parts and the engineers those are basically involved in the execution part. Heterogeneous traffic conditions prevailing in developing countries like India are more complicated. The impact of traffic congestion adversely affects the economy, health, environment and traffic safety, which is the major concern for the researcher to come up with the comprehensive and new dimensions to tackle these challenges. Lane discipline, though a major factor no work is described to measure the congestion indices with account of Lane discipline in mixed traffic environment. Although the number of non-motorized vehicle are not so high, but it plays a significant part in city network and its impact on traffic jam eventually may not be ignored.

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