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A Review on Economics of Traffic Congestion

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Abstract: ***Transportation is a basic social and economic need of the human for mobility and day to day activities and it becomes a predominant requirement in the present situation of rapid urbanisation to provide for both passenger and freight mobility within and out of urban areas. Traffic Congestion is one of the predominant problems i.e. being faced by the both passengers while commuting and by Traffic Engineers while optimising traffic problems. Engineers can come up with various kinds of solutions to this congestion problem, but choosing one among them is also a decision to take as economy and safety are concerns to keep in minds of them while doing so. So, Cost incurred by the traffic congestion should be calculated to decide how much investment for the infrastructure to be built or solution to be implemented can be decided. This review paper will discuss about the literature available on traffic congestion cost, value of time and monetary losses happening due to traffic congestion.***
Keywords: Congestion Cost, Pollution cost, Traffic, Travel Time, Value of Time.

I. INTRODUCTION

Traffic congestion has been one of major issues that most metropolises are facing and thus, many measures have been taken in order to mitigate congestion. It is believed that identification of congestion characteristics is the first step for such efforts since it is an essential guidance for selecting appropriate measures. Congestion - both in perception and in reality - impacts the movement of people and freight and is deeply tied to the history of high levels of accessibility and mobility. Traffic congestion wastes time and energy, causes pollution and stress, decreases productivity and imposes costs on society.

Until 1991 India's economic reforms, the Indian Transportation sector was like an entirely different scenario compared to now. Liberation Privatization Globalization (LPG) of the Indian Economy changed the complexion of Indian Transportation. In those times Public Transportation was the prevailing mode due to the presence of the License Raj system. But Post LPG reforms, an increase in incomes of individuals forced people to change to private mode of transportation from public transportation. The number of the private mode of vehicles in the past two decades increased exponentially. The rate of growth of registered vehicles is far more than the rate of growth of the population in India. But at the same time increase in road network density in either urban or rural areas is not meeting vehicle density even though India's road network is the second most dense in the world. This causes new problems in the Transportation sector.

Traffic congestion in one of the major problems that exist in the Transportation sector and is being faced by the Transportation Engineer. Traffic congestion is characterised by increased travel times, reduced vehicle speeds, and increased vehicle queuing. Traffic congestion of high intensity is bound to happen in Peak Hours. Mostly, these peak hours fall in the range of morning home to work going hours and evening work to home going hours. Poor working people in urban areas, who usually large in number reside in outer fringes of city for lower cost of living and rents. But they have to move into the city for their regular work. And most of the educational institutions are also present on the outskirts of the cities. Because of these both reasons, people have to travel long distances during peak hours, which in turn leading to huge traffic congestion.

So, we tried to drop some light on cost of congestion i.e. being led by different sub causes which are happening due to Traffic Congestion like Travel time losses, working hour losses, more precious fuel losses and losses occurred due to pollutant emissions from vehicles.

II. LITERATURE REVIEW

A. Overview of Traffic Congestion

Traffic congestion is a kind of internal friction developed in the vehicle flow, and resists the vehicle movement one by another, thus reducing the speed of the vehicles and thereby entire traffic flow. In other words, Traffic congestion arises when demand for the traffic movement is exceeded by the supply by the existing road space. This reduction in road space may arise due to various reasons like illegal encroachments of the pavement, uncontrolled growth of hawkers, irregular parking of vehicles on the pavement. Another reason for the congestion is reduction in speed of traffic flow. This traffic speed reduction is bound to happen due to ineffective management of traffic, improper installation of traffic signs, processions and Dharnas and accidents as it happening daily. Aparajita Chakrabtty and Sudakshina Gupta [1] observed congestion as a situation in which demand for road space exceeds supply.

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Congestion is the impedance vehicles impose on each other, due to the speed–flow relationship, in conditions where the use of a transport system approaches capacity. Congestion is essentially a relative phenomenon that is linked to the difference between the roadway system performance that users expect and how the system actually performs. They felt Congestion—both in perception and in reality—impacts the movement of people and freight and is deeply tied to the history of high levels of accessibility and mobility. Traffic congestion wastes time and energy, causes pollution and stress, decreases productivity and imposes costs on society. Authors believed that identification of congestion characteristics is the first step for such efforts since it is an essential guidance for selecting appropriate measures. Authors said There are two principal categories of causes of congestion: (i) micro-level factors which relate to traffic on the road; and (ii) macro-level factors that relate to overall demand for road use. Congestion is 'triggered' at the 'micro' level (for example, on the road), and 'driven' at the 'macro' level, by factors that contribute to the incidence of congestion and its severity. The micro-level factors are, like many people and freight wanting to move at the same time and too many vehicles in limited road space. Many trips may be delayed by events that are irregular, but frequent: accidents, vehicle breakdowns, poorly timed traffic signals, special events like mass social gatherings, political rallies, bad weather conditions, etc., are factors that cause a variety of traffic congestion problems. Macro-level factors, for example, land-use patterns, employment patterns, income levels, car ownership trends, infrastructure investment and regional economic dynamics also may lead to congestion.

B. Measurement of Congestion

Though congestion is the fundamental concern in dealing with any transportation problem, the degree of congestion on urban arterial roadways is not always measured and treated uniformly, mainly because congestion is not a very well-defined phenomenon. It is measured either for area-wise conditions or for a specific location. The measured quantity may be a parameter of the quality of flow that travellers experience (for example, travel time, delay and queue length) or a parameter of the flow characteristics (for example, density and occupancy). Congestion can be expressed also by the ratio between supply and demand or by the relative quality of traffic flow between ideal conditions and the prevailing conditions. The scale of measure may be a set of discrete classes (level of service [LOS] = A, B, C...) or a continuous value (for example, a number between 0 and 1). Different approaches and measures that relate traffic congestion to the traveller's perceived quality of flow are recommended by Levinson and Lomax [2] and Lomax et al. [3]. Traditionally, the use of LOS has been the most popular measure of congestion, in which the ratios between supply and demand are compared and put in one of six classes (A through F).

Turner SM. et.al. [4]'s work is one of the earlier researches done in the Traffic congestion problem area. They defined congestion as the travel time or delay encountered in excess of that normally incurred in light or free-flow travel conditions. Unacceptable congestion was defined as the time or delay beyond some agreed-upon norm. There was a need to separate the two quantities because of the varying perceptions of congestion by travellers in different city sizes, locations in the urban (or rural) area, and time of day or year.

They recommended that the direct measurement of travel times be used whenever possible to quantify the various dimensions of congestion. Numerous guidelines exist for travel time data collection, and they presented a summary of the previous data collection procedures on the basis of recent travel time analyses. Where direct measurement of travel times is not feasible, a variety of surrogate procedures were used to estimate travel time quantities. Estimation techniques were most applicable for policy, programming, and planning purposes, whereas direct travel time measurement provides valuable information for before-and-after studies, identification of bottle

necks, evaluation of various traffic control and management techniques, and air quality analyses. They set forth some simple equations for estimating freeway speeds on the basis of traffic volumes and interchange frequency, and for estimating arterial street speeds on the basis of traffic volumes and signal spacing.

C. Speed

Rao & Rao [5] have suggested several speed measures besides average travel speed. The average travel rate, in minutes per mile, is the reciprocal of average travel speed. Peak period nominal speeds are a weighted average of speeds on freeways and principal arterial streets, which allow comparison of the freeway and principal arterial street network between urban areas. the ratio of peak period to off peak period speed suggested as direct measures of congestion. Some of the approaches based on speed are described below.

1) *Corridor Mobility Index:* Corridor Mobility Index (CMI) is a measure of the person-carrying capacity of corridors (Lomax et al., 1997). the speed of person volume is the product of travel speed and peak-hour person volume per lane. CMI or rate of person movements has been defined as the product of peak-hour vehicle occupancy and travel speed.

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2) *Speed Reduction Index:* Speed Reduction Index represents the ratio of the decline in speeds from free flow conditions. It provides a way to compare the amount of congestion on different transportation facilities by using a continuous scale to differentiate between different levels of congestion. the index can be applied to entire routes, entire urban areas, or individual freeway segments for off-peak and peak conditions.

D. Travel Time

The use of travel time studies (Lomax et.al) [3] and related measures to explain about system performance and congestion was entered the traffic engineering literature as early as the late 1920s. the early studies concentrated on determining average travel speeds in congested areas and attempted to locate the amount and sources of travel delay. Some of the indices related to travel time are listed below.

1) *Travel Time Index (TTI):* Travel Time Index was proposed by Levinson's et.al [2]. Index compares peak period travel and free flow travel while accounting for both recurring and incident conditions. It is index is expressed by comparing travel time in free flow condition and the one in peak hours. Index has the advantage of expressing traffic congestion in terms of both space and time.
2) *Travel Rate Index (TRI):* Travel Rate index computes the "amount of additional time needed to make a trip because of existing congested conditions on the roadway." It examines how fast a trip can occur during the peak period by focusing on time rather than speed. The TRI is an indicator for entire portions of the analysed network based on the respective distance and number of vehicles supported by each section.
3) *Buffer Index:* The buffer index calculates the extra percentage of travel time a traveller should allow when making a trip in order to be on time 95% of the time. This method uses the 95th percentile travel rate and the average travel rate, rather than average travel time, to address trip concerns. The buffer index represents the reliability of travel rates associated with single vehicle. This measure may be beneficial to the public because it tells them how congestion will affect them as individuals.

In addition to above, there are few more indices like Misery Index, Travel rate, Congested travel, Congested roadway, Accessibility, Congestion Index also available based on the travel time in the literature.

E. Value of Time (VOT)

The value of travel time can be defined as the price people are willing to pay to gain an additional unit of time. The concept of VOT was introduced by R Becker [6] when he proposed the conversion of time into money by assigning more time to work. A combination of population growth, urbanization and increasing economic prosperity has led to significant congestion problems in many parts of the world, particularly in the urban areas.

Syed Fazal Abbas et.al [7] have carried out following study and observed as follows. Data for the VOT estimation was collected through a Stated Preference (SP) survey. A paper-based questionnaire was developed where respondents were given hypothetical mode options to choose from. The survey form comprised of two sections. The First section focused on socioeconomic data such as age, gender and income status. Furthermore, travel attributes such as origin, destination, mode, travel expenses and journey time were collected. The Second section of this survey was related to SP data. The options from which the respondent could choose were provided based on his current mode. A Multinomial Logit Regression Model (MNL) was implemented through utility theory by maximizing loglikelihood. The obtained coefficients of Travel Cost and Travel Time were divided to estimate the VOT. Based on these coefficients the estimated VOT is calculated to be 371.31 Rs/h, which is equivalent to 3.6677 US$/h. the VOT is calculated to be 98.67 Rs/h for other than car users, which is equivalent to 0.9752 US$/h.

Athira I C et.al. [8] have presented the estimation of value of travel time in case of work trips using combined RP-SP approach. The study revealed that the income and trip length have substantial influence on value of travel time. Data were collected by means of combined revealed - stated preference survey on representative sample of population in Calicut city by work place interview. Stated preference experiment was designed to capture the responses for estimating VOT values for work trips. Responses in the form of "choice" among the presented choice alternatives were utilized to develop utility models and the estimated coefficients from the developed models were used to estimate VOT measures. The results indicate that the VOT associated with work trips is higher in high income groups. As income increases VOT also increases. Similarly, trip length also has a positive influence on VOT. As trip length increases, VOT increases. Within the same trip length itself, VOT varies among different income groups.

Khan et al. [9] conducted a study "Cost estimation of Traffic Congestion in Dhaka City". They defined the congestion cost as composed of mainly costs, namely, travel time costs, vehicle operating costs and externality cost due to delay and environmental damages.

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The time spent on travelling has an opportunity cost and is the most important item cost of the total congestion cost which also includes Travel Time Variability losses, i.e. TTV, arising from unpredictability of the journey time. The study calculated Travel Time Costs, TTC (using Value Of Time, VOT approach) and Vehicle Operating Cost, VOC, due to traffic congestion directly while it makes allowances for TTV, Dead-Weight Loss, DWL- the avoidable social costs of congestion, externality cost due to travel time delay (imposed on others) and environmental damages. The total annual cost due to traffic congestion in Dhaka was obtained as about USD 3868 million per annum.

A study was conducted by Aditi Singh and P.K. Sarkar [10] on determination of congestion cost in central business district of New Delhi. They attempted to determine the congestion pricing in central area of Delhi that is Connaught Place with a view to ensure desired level of service. Two methods for the determination of optimal pricing were adopted. The first method was related to the point of pricing where the external costs are met by the revenue generated by the pricing level while the second method was the pricing level needed to maintain a level of service C. By using these methods, pricing for car and two-wheeler motorized vehicles were determined. According to this study the pollution cost per kg was Rs 7.22.

Tina Maria Sunny et.al. [11] conducted a detailed study on the roads of Thiruvananthapuram city, to determine where congestion pricing can be enforced to ease the congestion on the roads. A congestion performance measure named travel time index was estimated for the existing traffic of selected road corridors and the congestion level of these study stretches were identified. Authors carried out Willingness to pay survey to know the congestion price that needed to be adopted at the selected road locations. The congestion price for car users obtained was Rs 14.50 per kilometre. The study revealed that the value of travel time for car user was quite substantial. For car users, it was estimated to be of around of Rs 102.93 per hour. The study also revealed that the willingness to pay congestion charge by car users was also quite significant. 24% of car users were willing to pay Rs 10 while 17% of car users are willing to pay Rs 15 and 11% of car users were willing to pay than Rs 20. The result from the opinion survey was used to plot the demand elasticity curve for car users.

Manish Pal et.al [12] in their research work “Delay, fuel loss and noise pollution during idling of vehicles at signalized intersection in Agartala city, India” presented their work regarding fuel consumption quantities of vehicles in idling state. For measuring fuel consumption at idling condition for each vehicle, studies were carried out by filling fuel tank of vehicle completely and then the engines were run at idling conditions. The exercise was repeated several times to determine the average fuel consumption of the vehicles during idling. The revenue loss of fuel for each vehicle was calculated by multiplying fuel loss with the prevailing cost of fuel. Sarath Guttikunda [13] published extensive research work carried out by him in the area of air pollution from various sources in a series of working papers in the name of “SIM-air Working Paper Series”. He used a tool named “Vehicular Air Pollution Information System” (VAPIS). The VAPIS tool was developed to establish the emission trends and evaluate possible management scenarios for one vehicle category, using minimum inputs for the user. The tool can be replicated for multiple pollutants and multiple vehicle fleets, depending on the availability of the input data.

“Emission Factors”, by definition, represent the release of a pollutant due to combustion of fuel, with common units of gm/veh-km, under a variety of conditions, e.g., loaded and unloaded; idling; cold starts; and cruising. Sarath Guttikunda [14] have proposed Four Simple Equations for Vehicular Emissions Inventory for calculation of pollutant emissions being released in to the atmosphere by the Vehicular traffic. One of the equations was mentioned here.

Emissions (gm/day) = Daily Vehicle Volume (no/Day) * Average idling time (min/day) * Fuel consumed while idling (ml/min) * Emission factor(gm/km) * Fuel efficiency (km/lit)

Bivina G R et.al [15] discussed the estimates in monetary terms, the cost of traffic delay-increased travel time, increased fuel consumption and increased pollution, taking one of the corridors in Thiruvananthapuram, the capital of Kerala, India. Primary data collection such as speed and delay survey to estimate travel time delay along the selected corridor using floating car method, willingness to pay using questionnaire survey to estimate value of travel time savings, traffic volume survey and average passenger occupancy were conducted. Data analysis of willingness to pay survey was performed with the help of Microsoft Excel and models were developed to estimate value of travel time (VOT) by them. Finally, they estimated that in total Rs 83.85 Crores was being wasted annually on the Thiruvananthapuram City roads due to Traffic congestion by the year 2016.

Kanchal Dave [16] evaluated the congestion cost on the basis of fuel consumption and value of time and pollution from vehicular traffic. Two methods were adopted by the author to optimize the charges for congestion. First method was based on the charges required to generate revenue and other is charges required to maintain the LOS C. With the help of these methods, congestion charges are fixed. Marginal costs of Rs 23 and Rs 4.8 in normal hours and Rs 38.2 Rs 5.2 in peak hours for car and two-wheeler were calculated to nullify the external cost generated due to traffic. But, in order to reduce the LOS of traffic if road to C Charging fees of Rs 14.46 and Rs 8.6 were recommended by author for car and two-wheeler respectively.

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III.CONCLUSIONS

A. Now, discussion has been done about traffic congestion cost that occurred due to various reasons like time losses, fuel losses and losses due to vehicle pollutants that being released during traffic congestion.

B. Congestion is the impedance vehicles impose on each other, due to the speed–flow relationship, in conditions where the use of a transport system approaches capacity.

C. Value of Time of Car users and willingness to pay congestion charge of car users are quite high when compared to other mode of travels.

D. By extending and adding to the current knowledge additional inputs and research can be done and reframe the entire topic into more reliant and significant.

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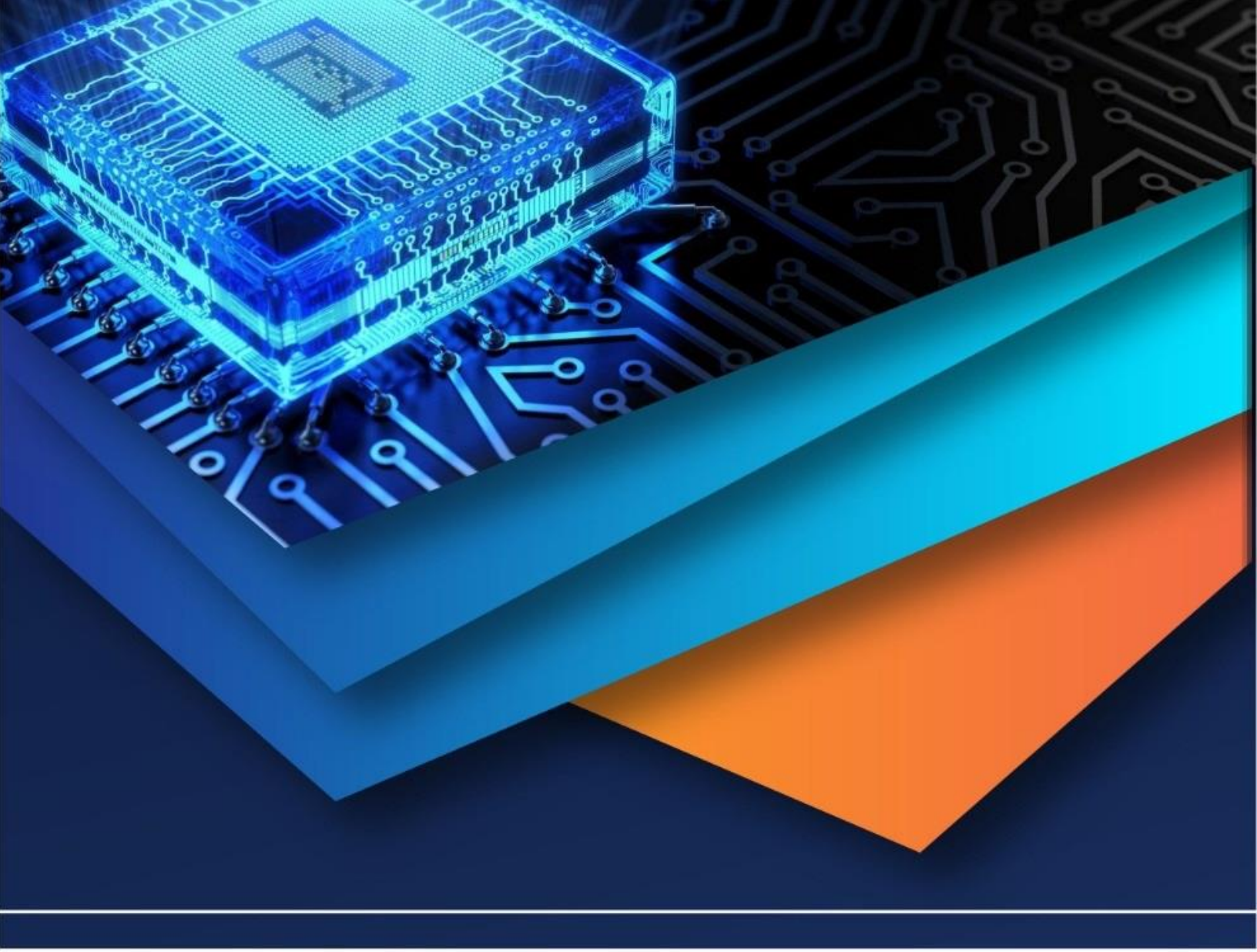

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