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The extent of traffic congestion in Guwahati, India: A multi index analysis

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ABSTRACT

Daily commute is a part and parcel of the human life but traffic congestion is a perpetual urban problem across the world. This paper measures the extent of traffic congestion in Guwahati, the largest city of Assam, India. Shifting commuters from the private vehicles to the public transport is often cited as the policy prerogative of transportation planning authorities across the world. The cited benefits are less traffic congestion, lesser environmental and energy issues. To achieve this end measurement of the extent of traffic congestion as well as understanding the modal choice of the commuters need are prerequisites and should be at the centre of policy making. Based on a sample of 400 daily commuters across the Guwahati city and with the help of a structured bi-lingual questionnaire we collected the responses on five point Likert scale. We found that traffic congestion is prevalent in all the three zones of Guwahati as per the Travel Time Index criteria but its of "mild traffic congestion" category in all the three zones of "traditional areas", "newly established areas" and the "commercial areas" of Guwahati as per the Speed Performance Index.

Key words : *Mobility, Traffic congestion, Guwahati, Travel Time index, Speed Reduction Index, Speed Performance Index.*

Introduction

People are mobile for learning, earning income, getting medical treatment and pleasure. With the development of transportation technologies, the mode of transport has changed for daily commute. The daily mobility became safer, easier and faster with the invention of motor vehicles until the urban areas experienced a new type of problem designated as traffic congestion. Frequent traffic congestion is experienced by the commuters living in the cities of both the developed and developing world.

The city dwellers of both the developed and developing world experience the traffic congestion frequently. Extreme dependence on automobiles is one of the aspects of urban travelling causing traffic congestion in the streets of the cities (Meyer and Miller, 2001). It's a serious and genuine problem whose solution is yet to be explored properly. Traffic congestion cause increased fuel loss (Wurhofer *et al*., 2015), more vehicle operating cost (Jayasooriya and Bandara, 2017), air pollution (Lu *et al*., 2017), noise pollution (Alam, 2011), psychological stress of the commuters and drivers (Lucas and Heady, 2002) and is characterized by loss of time of the commuters (Verhoef and Rouwendal, 2004).

Traffic congestion is a genuine and pressing urban issue of modern times leading to loss of money in visible ways such as increased vehicle fuel cost of the commuters at micro level, more monitoring cost in the form of deployment of traffic personnel on duty or installation of sophisticated traffic management system including but not limited to installation of CCTVs and/or speed detection cameras, traffic

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surveillance system, creation of new road infrastructure such as alternate routes, flyovers, ring roads across the cities and hence increasing the fiscal burden of governments and invisibly it eats up the valuable time of the people and businesses.

The existing literature on traffic congestion in Guwahati have focused on air and noise pollution, road network analysis using GIS but the literature to measure the extent of traffic congestion are very scant. Besides, most of these studies have ignored commuters' perspective and their problems as well. Reaching destination on time is aspired by every commuter in urban areas as well as prerogative of the authorities. The traffic congestion is an impediment to achieve this goal. The problem of traffic congestion is responsible for loss of time which can cause not only huge losses to business but is also responsible for mental stress to the students who are going to set for their examinations or even cause death to the patients in ambulance if the destination is not reached in time. This makes it necessary to understand the extent of the traffic congestion in city.

Therefore, the main objectives of the present study is to measure the extent of traffic congestion in Guwahati, the largest city of entire North East India in terms of area and population as well the number of vehicles.

The present study is divided into five sections. The introduction section sheds light on the importance of the studies on traffic congestion. Following that the literature review section explores the problems created by traffic congestion, the coping strategies of the daily commuters to deal with the anticipated traffic congestion, the innovative market based tools to contain traffic congestion, thereafter, the methodology section presents a description of the study area, the sampling procedure, the zoning of the study areas and the indices to measure the traffic congestion. This is followed by the result and discussion section which presents the analysis of the result with brief discussions. Finally, the conclusion section provides a gist of the study.

Literature Review

People migrate to urban areas in search of better earning opportunities and improved standard of living, but the urban liveability is adversely affected due to frequent traffic congestion (as well as other factors). Traffic congestion affects the life of the city dwellers in many ways. Apart from the loss of time and pollution, people tend to get frustrated due to traffic congestion induced over journey (Wurhofer *et al.*, 2015). Psychological stress is often associated with a congested-road journey (Koslowsky, Kluger and Reich, 2013). As traffic congestion is a frequent phenomenon that causes stress, people discuss the problem of traffic congestion with their peers (Poerwandari, 2022). This shows that traffic congestion has deep impact in the lives of the people. In this regard, Lucas and Heady (2002) in their study have found that irrespective of the gender, the commuters with flexible working hours, experience lesser stress than those with fixed working hours. Another study in urban China reveals that daily commute time to work does affect the overall life satisfaction as well as happiness of the commuters. This is more veritable for those commuters who commute more than one hour on daily basis. The compensation for loss of wellbeing of the employees is 82 yuan per hour of commuting (Nie and Sousa-Poza, 2018). This shows that the issue of traffic congestion is not just a temporary daily affair but it has deep rooted impact in the life of every city dweller.

As a response to the daily traffic congestion in the metropolitan areas, people have developed certain coping strategies. First, there is evidence that people use telecommunication as a coping strategy to avoid the stress of commuting on a congested road (Novaco and Gonzalez, 2009), third they keep extra travel time at hand and third, people prefer to own/rent house near their workplace to beat the traffic. In a longitudinal study by Novaco, Stokols and Milanesi (1990) it is observed that peoples' job change is primarily affected by the commute satisfaction and the existing literature suggests that congestion is a factor affecting the same, so traffic congestion mediates to the job selection of the people over a long period of time. These evidences reflect that the problem of traffic congestion is too important to ignore.

Literature argues that a balanced use of public transport and private automobiles may ensure a desired level of mobility amongst the urban commuters (Aftabuzzaman, 2007) but this "balance" is not clear for the cities of the future (Owen, 1992) particularly because the contemporary urban society is witnessing a trend of micromobility (Abouelela, Al Haddad and Antoniou, 2021). The term micromobility is defined by the (ITF, 2020) report as "….*the use of micro-vehicles: vehicles with a mass of no more than 350 kg (771 lb) and a design speed no higher*

than 45 km/h."

Management of the on-road traffic is a major challenge across the world. The traffic related problems and particularly traffic congestion is more pronounced for fast growing cities of the developing countries. The reason is the rate of growth of transport infrastructure is slower than the growth rate of vehicles on road (Santos *et al.,* 2010) and the scarcity of land to be used for the road as well. The traffic infrastructure like creation of flyovers, making foot bridge etc. are temporary solutions to ease the problem of traffic congestion. From economic perspective traffic congestion is a situation of supply deficiency, a situation where the supply of the available road space is less than the demand for the same. So the policies to manage traffic congestion should focus on either containment of demand for the road space or to increase the supply of the same so the traffic can move freely in the desired direction.

The most common response of the governments across the globe to deal with traffic congestion is to expand the road capacity by building new road infrastructure or making provision for alternate means of transport such as monorail or bullet trains. All such projects cost huge monetary burden to the governments and ultimately the citizens bear the cost in the form of increased taxes of various sorts.

If the problem of traffic congestions is viewed as the situation of excess demand, a situation where the demand for the available road space exceeds it supply then deployment of market based economic strategies to contain congestion could be logically argued. The market based strategy to reduce the cost of congestion are easier to enforce as it requires smaller bureaucracy to administer and its instruments are more difficult to evade than most congestion-reducing regulations (Anas *et al.,* 2009). Its comparatively easier to identify those who don't pay for the congestion toll on a highway than to ensure that a specific percentage of the people are not driving alone to their place of work. The major complaint against the congestion pricing system is that they are regressive on the people with lower income strata but there are counter arguments to state that most of the people with lower income travel by city bus would not have to pay the congestion toll. Countries such as UK (London Congestion Charge) and Singapores' Congestion pricing strategies have been successful (Leape, 2006; Santos, 2005) to contain congestion with the market based tool of quotes.

The economic aspects of traffic congestion are mostly negative, like loss of time and income of the people and business (Verhoef and Rouwenddal, 2004), increased pollution and fuel loss (Esfandabadi *et al.,* 2020). In this regard, if we assume that wage earned is a positive function of the time invested in work (which is true for most of the people working in the unorganised and semi-organised sector), then more congested travel time is surely a cause of loss of income to the workers. This phenomena is more relevant for those who are engaged in food delivery apps (Swiggy and Zomato valets) and the courier delivery persons, drivers of the public passenger vehicles (unless they are following a congestion adjusted dynamic fare system, which is mostly the case in the city of Guwahati for all of the auto-rickshaw, bus, magic and e-rickshaw drivers) as their income is based on the number of deliveries or the number of passengers carried from origin to destination.

There has been attempts to measure the traffic congestion with the help of historical data (Chiabaut and Faitout, 2021; Xu *et al.,* 2013) and an increasing trend with the contemporary researchers to measure the same with the help of real time data collected through the stationary sensors and artificial intelligence (Akhtar and Moridpour, 2021) and probe data as used by Google maps in the developed world is observable. Some more recent studies like (Adetiloye and Awasthi, 2019; Zhu *et al.,* 2019) have combined the historical and probe data to better explain the extent of traffic congestion. However, Akhtar and Moridpour (2021) in their literature review paper claimed that till date most of the studies use the historical data to measure and forecast the traffic congestion.

Certainly, Indian cities in general and that of North East India in particular are not exception to traffic congestion. In North East India, the research papers pertaining to traffic related issues are mostly Assam and Guwahati specific. Studies pertaining to other cities of the North East India are very thin with an exception to Shillong. In Shillong, Meghalaya, due to hilly terrain and narrow roads and very rapid urbanisation traffic congestion is a frequent phenomenon and it is responsible for a rise in the average annual fuel cost from 45.73 per cent to 134 per cent at various locations of the city in comparison to the free flow conditions (De and Rajbongshi, 2020). In Guwahati city, studies pertaining to noise pollution due to road traffic was found to be 88-90 dB in commercial locations, educational institutions, hos-

pitals and nursing homes that are located in the noisy environment of Guwahati (Alam, 2011; Islam and Kalita, 2017).

The demands of the public transport service providers such as city bus owners, cab and auto-rickshaw unions are listed by the authorities because of their collective bargaining power, this is however, not the case with that of passengers as the passenger unions don't exist. Passengers being the consumers, their aspirations affect the demand side of the equation and any policy regarding public or private transport shall not yield the desired outcome. Currently, the authorities have covered the issue of safety of the passengers by means of vehicle fitness certificate, deployment of traffic police on road, mandatory insurance of the vehicles, uniform of the bus drivers and conductors besides to ensure that air pollution remains under control and does not affect the commuters primarily pollution under control certificate is made mandatory. The traffic characteristics like congestion and prolonged traffic jam do affect the psychological state of the people and requires deep understanding. Quantification of the extent of traffic congestion is of immense value for the transport planners and other stake holders.

Methodology

Study area description

With an administrative area of 216.79 square kilometers Guwahati is the largest metropolitan city in the north east India. At present the city of Guwahati has mainly three national highways NH 31, NH 37 and NH 40. While the National Highways are connecting the city to the rest of the country, such highways are on the outskirts of the city. Our study focuses primarily on the Public Works Department (PWD) arterial roads which connects the various locations at intra city level.

The Guwahati Municipal Corporation (GMC) is the local body entrusted with the governing, planning and management of the city. For the purpose of data collection we conducted a field survey in the GMC area during March-May, 2021.

Due to non-availability of historical data in the public domain and the absence of sensor based probe data for traffic in the city of Guwahati we were left with no other choice but resort to primary data collection by means of a self-structured questionnaire.

To select the sample size we used the Taro-Yamane formula of sampling as shown below

Map 1. Study area (Guwahati City) Marked in red coloured border.
Source: Google maps 2021

$$n = \frac{N}{1 + N(e)^2} \quad .. (1)$$

Where n is the sample size, N is the size of the population, e is the margin of error which is taken to be 0.05. The population of Guwahati city is 11.2 lakhs as per census 2011 and following the Taro Yamane formula of sample size selection, 400 sample size is taken into consideration. Two stage sampling is conducted to ensure heterogeneity of data. Pretesting of the questionnaire was conducted during March 2021 with 15 respondents to understand the issues in comprehension of the questions and necessary changes were made to make the questionnaire easily comprehensible to the respondents.

Zoning areas

The arterial road intersections were chosen as the data collection point where the respondents were chosen randomly. This practice ensured that the respondents so chosen are definitely commuters to that locality. This helped us to choose respondents from across the city and thereby inclusion of heterogeneous population could further be ensured. Since commuters are mobile we collected data from the commuters living in 40 different locations of the city. These locations have been broadly classified as commercial areas, traditional areas and the newly established areas for further analysis.

The primary data has been collected with the help of a self-structured Anglo Assamese questionnaire for the ease of the respondents. Before constructing the questionnaire, three standard questionnaires namely Transport Survey Questionnaireof University of Sussex (2021), School Travel Questionnaire prepared by London Borough of Hounslow (2020), Transportation Survey for Employees prepared by National Centre for Mobility Management (2013) have been reviewed. These questionnaires

shed light on the variables to be included to assess the extent of traffic congestion. The variables included in for our self-structured questionnaire are mainly form literature review, discussion with the commuters and the experience of the authors as commuters in the city since their birth such that they can reflect the overall perspective of the commuters on the existing traffic system of the city and be consistent with the objectives of the study.

The literature provides a long list of measurement indices and methods of measurement of traffic congestion in a congested roadway. The time based congestion measures are included in the present study. One of the widely used time based traffic congestion index is Travel Time Index (TTI). TTI was first proposed by the Urban Mobility Report (Schrank and Lomax, 2005). This index compares the travel time in the free-flow conditions and during the peak hour congestion.

$$TTI = \frac{Peak\ Period\ Travel\ Time}{Free\ Flow\ Travel\ Time} \quad .. (1)$$

Another method for measurement of traffic congestion is the Travel Rate Index (TRI) which measures the amount of additional time required to make a trip because of the traffic congestion on the streets (Levinson and Lomax, 1996). The merit of the travel time index is that it is easy comprehensible to most of the people.

Among the speed based congestion indices Speed Reduction Index (SRI) is a popular index. It is defined as the ratio of relative speed change between congested and free-flow conditions

$$SRI = 1 - \frac{v_{ac}}{v_{ff}} \times 10 \quad .. (2)$$

Where SRI is the speed reduction index, v_{ac} denotes the actual travel speed, v_{ff} refers to the free-flow speed. The SRI ratio is multiplied by the 10 to get the value in the range of 0-10. Congestion is said to occur when the SRI value exceeds 4. Any value less than 4 is the refers to the situation of non congestion (He *et al.*, 2016; Rao and Rao, 2012).

The Speed Performance Index (SPI) is extensively used for of urban road traffic evaluations in the literature (Rao and Rao, 2012). It is simple to understand for the masses as well. SPI is the ratio of the average speed of the vehicles and the maximum possible speed. There are three threshold values to measure the same (25, 50 and 75).

$$SPI = \frac{V_{avg}}{V_{max}} \times 100 \quad .. (3)$$

Where SPI is the speed performance index, v_{avg} is the average speed of the vehicles the v_{max} is the maximum permissible speed of the vehicles at road. The Public Works Department (PWD) roads inside the city has a maximum speed of 40 kmph.

Table 1. Speed Performance Index

Speed Performance Index	Congestion level
0-25	Heavy congestion
25-50	Mild congestion
50-75	Smooth
75-100	Very smooth

Source: Rao and Rao, 2012

Results and Discussion

The twenty first century has been marked by rapid, sustained and widespread rise in the number of vehicles across the first, second and third world countries. Certainly India in General and Assam in particular are not an exception to this increasing trend of vehicle ownership by the masses. To understand the extent of traffic problem we have taken help of secondary data.

The secondary data shows that India has a vehicle density of 225 vehicle per thousand persons in the year 2019 and is increasing rapidly since 2001. Assam has also witnessed the growth of 12 per cent increment in vehicle registration in the year 2021-22.

Population Density

The vehicle ownership per thousand population in

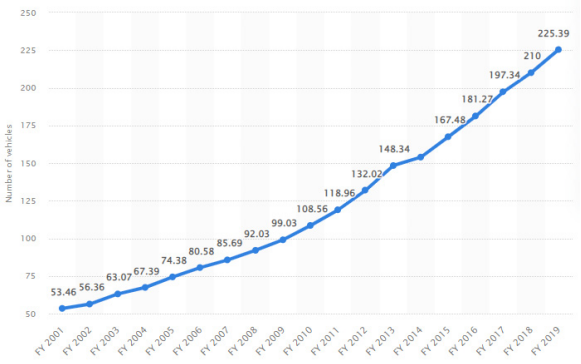

Fig. 1. The increasing vehicle ownership per thousand population in India.

Source: Road Transport Year Book 2017-18 and 2019-2020

India is growing steadily over the last 20 years (Figure 1).Certainly Guwahati is not an exception and the population density of Guwahati city is growing continuously (Figure 2) leading to increased pressure on the scarce resources including but not limited to water, land, forests resources and on the available road space. This is because irrespective of the ownership of vehicle, mobility is a daily need for almost every section of the society to reach school/office/place of work or market. If this assumption is true, than there will be demand for vehicles private or public to reach the daily destination leading to more intense utilization of the available road space. This is reflected in the number of vehicles registered in the Kamrup (Metro) DTO of which Guwahati convers the majority the vehicles over the years.

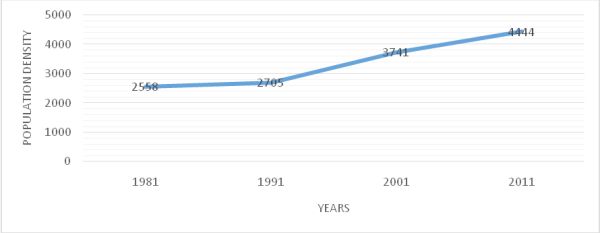

Fig. 2. Decadal population density in Guwahati.
Source: Prepared by authors with data from Ministry of Urban Development, Govt. of India. (2016).

A linear trend line is fitted to observe the trend of vehicle registration in Kamrup Metro district, Assam and as expected the vehicle registration has an increasing trend over the years (Figure 3). Due to COVID-19 induced lockdown, most of the people experienced a fall in their purchasing power leading to a fall in the vehicle sales in the year 2020-21.Infact, there was a fall of 23.74 per cent in vehicle registration owing to the pandemic. The vehicle sales and (hence registration) figures went up by 14.12 per cent in the Kamrup Metro in the year 2021-2022.

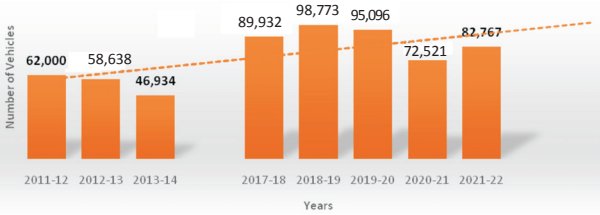

Fig. 3. Registered motor vehicles in Kamrup Metro District Transport Office.
Source: Prepared by authors from the data source Ministry of Urban Development Govt. of India (2016).

This figure could have been much higher but the shortage of electronic chips globally compelled the vehicle manufacturers to reduce production and there has been long "waiting period" for the cars booked ranging from a few months to even one year. In the year 2021-22 out of 33 districts of Assam, Kamrup Metro registered the highest number of vehicle registration (82,767) followed by Nagaon District with 26,476 number of vehicles. Kamrup Metro with an area of just 1,528 square kilometre is smaller than the Nagaon (area 2,287 square kilometre) district by 759 square kilometre, but the number of vehicles registered in Kamrup Metro district is 3.13 times higher than that of Nagaon. This is a clear indication that the traffic condition in Kamrup Metro needs immediate attention. The roadway capacity could not keep pace with the increasing number of vehicles on road and naturally congestion has resulted in the urban areas. Not only the number of passenger vehicles are increasing but the amount of passenger vehicle kilometres travelled are also increasing across the nations over the years.

With the rising focus on Act East Policy and India's multilateral agreements with ASEAN countries in the near future, the burden of traffic is bound to increase in Guwahati city and hence evaluation of economic cost of traffic congestion of the city is the need of the hour.

The demographic profile of the respondents is presented as under

With mean age of 29.49 years (SD 10.64), the commuters covered in the survey are young (Table 2). The mean monthly income of them stands at 34518.3 INR (SD 44355.2) and the monthly expenditure on transport stands at 2337.6 INR. In this regard, our study found that for an average commuter in

Table 2. Demographic details of the respondents

Groups	Mean
Age	29.49
Income (INR)	34518.3
Monthly Expenditure on transport (INR)	2337.6
Years of education	13.3
Occupation (in percentage)	
Govt. job	15.3
Private job	24.0
Business/self employed	23.5
Job seekers	37.3

Source: Authors' calculation from field survey.

Guwahati the percentage of monthly income spent as transport expenditure stands at 10.13 percent. This further emphasises that daily commute in general and traffic congestion in particular are not petty issues and needs rigours studies as it affects majority of the people in the society. The respondents of our mainly are the job seeker, businessmen, private job and government job holders with decreasing order of participation.

Mode of transport

The modal share of traffic implies the percentage of commuters using a particular type of transportation. It reflects the popularity of the means of transport in any city.

The modal share of traffic in any city determines the people's usage pattern of the mode of transport. This is important to understand the preference of the commuters. In Guwahati we found that city bus service is the major mode of transport for 42.9 per cent of the commuters (Figure 4). The city buses ply on the arterial roads of the city and connects the major areas on fixed routes but the buses don't run on sub arterial areas due to the narrow widths of the roads. This makes it difficult for the city buses to reach. The personal four wheelers are used by 26.80 per cent of the respondents. This makes it difficult for the commuters who are living in areas away from the arterial roads to get door step service of the city bus. The second popular means of public transport in Guwahati is personal four wheeler followed by carpooling/ola/uber/share taxis, own two wheelers, bike taxi, bicycle, reserved auto-rickshaw, office vehicle and walking. Walking is the least preferred mode of transport used mainly to cover the short term distances.

The two wheelers are used mainly because of the better manoeuvrability but the comfort of the four wheelers like prevention from heat and rain could have been the reasons for the choosing them as the second most preferred mode of transport by 26.8 percent of the commuters. Office vehicles are not accessible to everyone making such vehicles second least used means of transport after walking. Walking is used by the people to cover small distances only.

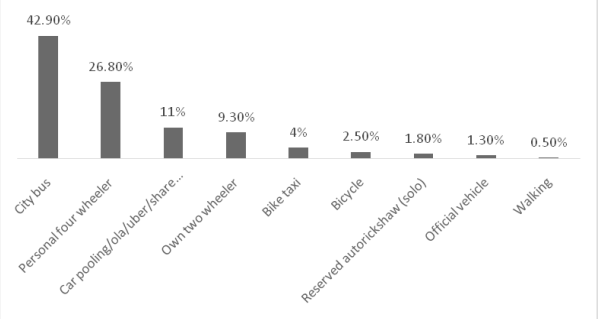

Fig. 4. Modal share of transport in Guwahati.
Source: Authors' calculation from field data.

The city residents exeperiece a harrowing time during the office hours of morning as well as evening. Both morning time congestion and congestion at the time of evening are problematic for 77.5 per cent and 74.5 per cent respondents respectively (Figure 5). More than half of the respondents avoided visiting the crowded place due to fear of getting stuck in traffic jam in the period October, 2020 to March, 2021. This clearly indicates that traffic congestion is a serious issue for the commuters in Guwahati.

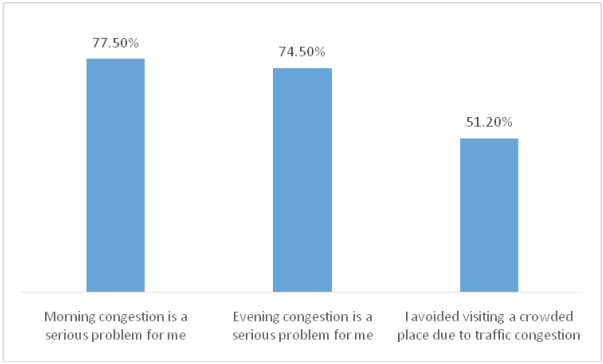

Fig. 5. Congestion problem for the commuters.
Source: Authors' calculation from field survey.

Extent of Congestion

The extent of traffic congestion is measured in terms of four indices as discussed above, i.e. Travel Time Index, Speed Reduction Index, Speed Performance Index.

Table 3. The extent of traffic congestion in Guwahati based on TTI, SRI and SPI.

Zones	Travel Time Index	Speed Reduction Index	Speed Performance Index
Commercial areas	1.59	3.24	31.96
Traditional areas	1.53	3.02	48.05
Newly established areas	1.65	3.18	40.27

Source: Authors' calculation from field data.

The travel time index (TTI) is the ratio of travel time during the peak period to that of free flow condition. We calculated the TTI to for the three zones namely commercial areas, traditional areas and newly established areas to see if there is a difference in the extent of traffic congestion based on the zones. The higher the TTI, higher is the extent of traffic congestion, provided TTI figure is more than 1. The travel time index in all the three zones is more than 1 this shows that traffic congestion is not limited to any specific area of the city rather its evil effect is felt by almost every citizen living in all the zones of the city. Quite opposite to our hypothesis that commercial areas the most congested areas and hence should have the highest travel time index but the commercial areas are second in terms of travel time index and the newly established areas people posits the highest travel time index.

A possible reason for high travel time index in the newly established areas could be that the frequency of public transport service is less in those areas. In our study many respondents opined that city buses run on the designated routes based on hourly basis on such areas, the magic drivers start their journey only when the vehicles are full with passengers thus, increasing the travel time for those passengers who sat early in such vehicles, besides those passengers who live in between the origin and destination route of the magic/e-rickshaws have to wait for a long time to get a magic/e-rickshaw to board on as most of the time such vehicles remain full with passengers besides the cab aggregators like Ola, Uber, Peindia drivers are reluctant to go to the newly "established areas" as they are not "passenger hotspots" implying a return journey with empty passenger seats leading to economic loss to the cab drivers. All these factors combined together could lead to more travel time index in the newly established areas of the city. The passengers assume the travel time from the moment they leave their home and marks an end to it as soon they reach their destination. This is an inherent drawback of our survey based analysis.

The speed reduction index is also used to express the status of traffic congestion in the literature. As per the SRI the traffic congestion is said to occur if the SRI value is more than 4. Our results (Table 3) suggest that none of the zones have attained SRI=4 but commercial areas of Guwahati experience the highest speed reduction due to traffic congestion (SRI=3.24), followed by newly established areas and traditional areas respectively. This indicates that traffic congestion in Guwahati is non-existent but it's on the threshold of getting traffic congestion (as SRI values of all the zones are more than 3 and approaching towards 4)

As per the SPI figures all the three zones of Guwahati are experiencing "mild congestion" (as all the zones fall in SPI range of 25-50). The commercial areas are exhibit an SPI figure of 31.95 which is very close to the range of 0-25, i.e. heavy congestion. This is followed by newly established and traditional areas respectively.

Coping with traffic congestion

Congestion being a frequent evil in the streets of Guwahati the commuters have developed some coping strategies to deal with it. The coping strategies of traffic congestion can be broadly categorized as govt. policies and behavioural changes. A few of the government policies aimed at reducing the traffic congestion is through reducing the complex behavioural changes of the commuters. Some other government policies are aimed at major institutional changes or strong financial incentives. One behavioural change is to avoid visiting the congested areas.

Congested areas are not liked by many because they are characterised by the slow traffic speed, lack of adequate parking facilities etc. 51.20 per cent of our commuters avoided visiting such places in the period of October 2021-March 2022 (Figure 6). The remaining 48.80 per cent of the respondents had compulsion to go there because of the business activity, schools or home. Generally, the congested areas are the commercial areas of the city, since traffic congestion and the associated problems of parking prevent psychologically around 51.20 per cent of the commuters to the visit such places, trade can further

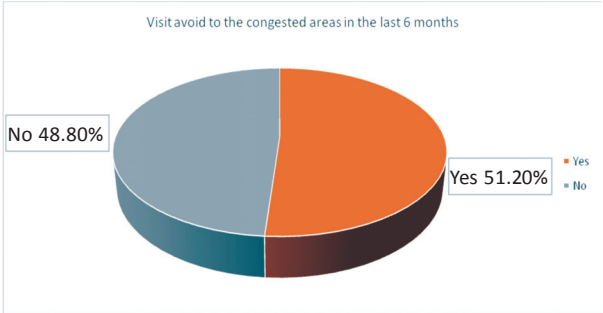

Fig. 6. Avoid visiting the congested areas in the last 6 months.

Source: Prepared by authors from field data.

be boosted up to a great extent by solving the issues of traffic in such areas or else if the businessman of such areas resort to home delivery service then traffic may get evenly distributed and not just concentrate in such locations.

People have adopted some other coping strategies to deal with traffic congestion. One widely popular way to deal with the expected congestion is to keep some extra time at hand whenever moving to any destination. Our study reveals that currently, the people of Guwahati on average keep 18 minutes extra at hand for their daily commute. Of course this travel time uncertainty increases with the increase in the distance to be covered and other traffic as well as road characteristics. In this regard it's interesting to note that despite keeping 18 minutes extra 74.1% of the respondents have been late in reaching their destination during the period of October 2020 to March 2021.

Conclusion

Traffic congestion is prevalent in all the three zones of Guwahati, namely "traditional areas", "commercial areas" and "newly established areas" as per the TTI. By strictly following the criteria of the SRI the traffic congestion does not exist in all the zones of Guwahati (as none of the zones have an SRI of more than 4) but the commercial areas are more susceptible to traffic congestion as it has the highest SRI value of 3.24 followed by newly established areas (SRI=3.18) and the traditional areas (SRI=3.02).

Since both the TTI and SRI are presenting two contradictory results due to inherent limitation of the methods, a more reasonable result is rather explained by the SPI which can be interpreted that the overall traffic congestion is "mild". With SPI of 48.05 the traditional areas are very close to experience "severe traffic congestion" in near future.

We observed that each method of measurement of traffic congestion can give different levels of traffic congestion. The authorities need to check the traffic congestion by different measures but while at the policy preparation process the method that shows the highest level of congestion should be taken into consideration. This becomes important to keep the future flow of traffic at least at the present level, to ensure sustainable transport.

Understanding the extent of traffic congestion could have been more inclusive had we included the parking characteristics in the city. This is a limitation to the present study. Future studies can undertake further research elaborately understand the traffic congestion in Guwahati.

Conflict of Interest

The authors declare that they have no competing interests.

Ethical Declaration

All procedures performed in studies involving human participants were in accordance with the ethical standards of the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all students included in this study.

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