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Traffic congestion assessment in a medium-sized Indian city: A case study of Agartala

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Abstract

Congestion on roads is a burgeoning problem not only in the big metropolitan cities but also in smaller municipal areas. Assessing traffic congestion in these urban areas is essential. This paper analyzes the nature of traffic congestion on selected roads within the Agartala Municipal Corporation (AMC) area and measures congestion stretches using Google Live Maps and primary surveys during morning and evening peak hours. Thirteen roads were selected and classified according to their functional roles as city-centre gateways, central business district (CBD) roads, and major east–west and north–south arterials. The results show that Motor Stand road, H.G.B. road, Dhaleswar A.A. road and Agartala–Sabroom road are the most congested corridors within the AMC area. A comparison of manual and Google Maps–based congestion measurements using Bland–Altman analysis and t-tests shows strong agreement, with no statistically significant differences. These findings confirm that Google Maps can serve as a reliable and efficient alternative for urban traffic congestion assessment for formulating effective strategies and implementing necessary measures to mitigate traffic congestion.

Keywords: *Traffic congestion; traffic composition; traffic signaling; waiting time; congestion stretch.*

Introduction

While traffic congestion has received considerable scholarly attention in India, much of these is confined to big cities leaving an impression as if the problem is less severe in smaller order towns and cities. The lived experience in many small and medium sized towns in India and many other developing countries however tell a different story where traffic congestion often leads to the stagnation or slowing of vehicles, commonly experienced as traffic jams, (Noor *et al.*, 2021) and is widely recognized as one of the most complex challenges in urban transport, significantly reducing mobility and making urban life increasingly uncomfortable for city residents. Consequently, a rigorous evaluation of congestion levels across road networks has become an indispensable element of contemporary traffic management and control. Given that congestion is inherently both time- and space-specific, a systematic assessment of these spatial and temporal parameters is essential. This methodological approach facilitates the achievement of smooth, convenient traffic flow without necessitating premature or capital-intensive investments, such as road widening or the construction of alternative pathways, unless absolutely vital. Current scholarship suggests that targeted interventions at intersections (Anciaes *et al.*, 2025; Hao *et al.*, 2017) can play a pivotal role in this process. Strategic intersection management not only enhances individual work efficiency by reducing transit delays but also optimizes the broader operational efficiency of city-wide mobility. The present study is positioned within this theoretical and practical framework, aiming to bridge the existing research gap in smaller-order urban centers.

Numerous studies across different geographical contexts have examined the causes, patterns, and impacts of urban traffic congestion, primarily focusing on large metropolitan cities and major transport corridors (Lieberthal *et al.*, 2024; Marazi *et al.*, 2023; Shokry *et al.*, 2025; Singh *et al.*, 2023; Ulvi *et al.*, 2024; Zhao *et al.*, 2022) contributing significantly to understanding congestion dynamics, travel delays, environmental consequences, and management strategies. Disproportionate attention on megacities is understandable due to their higher economic importance, stronger policy visibility, and better access to advanced traffic monitoring infrastructure, whereas medium-sized cities in developing countries often receive limited scholarly attention due to systematic data collection mechanisms. Medium-sized cities in developing economies face a unique combination of transport-related challenges, including rising vehicular ownership, constrained road space, mixed traffic conditions, and limited financial and technological resources for traffic management. Despite their growing demographic and economic importance, systematic congestion assessment in these cities is still sparse. This gap in knowledge limits the formulation of context-specific and evidence-based transport policies. Addressing this gap is particularly important as congestion in medium-sized cities is increasingly affecting urban mobility, environmental quality, and overall livability. Moreover, traditional congestion measurement methods, such as manual traffic counts and field surveys, are time-consuming, labour-intensive, and spatially restricted. In recent years, navigation-based platforms such as Google Maps have emerged as potential tools for real-time traffic monitoring, yet their reliability and applicability for scientific assessment and planning purposes require careful validation. This paper explores the spatial pattern of urban traffic congestion and evaluates the reliability of Google Maps–based congestion as an alternative to conventional field-based measurements in the mid-sized city of Agartala, the capital city of Tripura state of India. The study examines four key aspects: (i) identifying congestion-prone corridors and measuring the spatial extent of congestion using both field surveys and Google Live Map; (ii) analyzing traffic composition on selected urban roads to understand congestion characteristics; (iii) generating peak-hour congestion maps to visualize spatial variability in traffic conditions; and (iv) statistically validating Google Maps–derived congestion measurements through comparison with manual observations.

The city of Agartala is one of the most populous cities in northeastern India, exemplifying the emerging congestion challenges. In recent years, the city has experienced rapid population growth and increasing private vehicle ownership driven by socio-economic development and changing mobility preferences. However, much of its road network and intersection geometry were designed decades ago (Pal *et al.*, 2011). These outdated designs, coupled with limited carriageway widths, now struggle to handle present-day traffic demand, leading to frequent congestion along major corridors and at key intersections (Saha & Chakraborty, 2023). Peak-hour delays exceeding acceptable limits have become common, reflecting structural inefficiencies in the existing transport system. Prolonged congestion during peak hours affects commuter productivity, increases fuel consumption and emissions, and elevates stress levels among road users. More critically, frequent congestion severely hampers the movement of emergency vehicles during accidents and medical emergencies, potentially delaying life-saving interventions. These impacts highlight the urgent need for a systematic assessment of congestion patterns to support effective traffic management and urban planning interventions.

Although several studies acknowledge congestion issues in Agartala, there remains a lack of integrated and corridor-level analysis combining field-based observations with emerging digital traffic data sources. This represents a clear research gap, particularly given the growing reliance on such platforms for real-time traffic information and planning decisions. The present study therefore aims to assess the nature of traffic congestion along selected road corridors in Agartala city using a combination of field surveys and with the help of Google Live Map. Specifically, the study contributes by identifying congestion-prone corridors and measuring the spatial extent of congestion, and statistically validating the reliability of Google Maps–based congestion measurements through comparison with manual field observations. By addressing these gaps, the study provides empirically grounded insights that are directly relevant for urban planners and policymakers seeking cost-effective and scalable tools for congestion assessment and transport planning in medium-sized cities.

Study area

Agartala municipal corporation is the oldest municipal body in northeast India. It is situated in West Tripura District with a total area of 76.504 km^2 and a total population of 4,00,004 according to 2011 census. Currently the population is estimated at 584,000. Agartala, the second largest city in northeastern India, is situated near the Bangladesh-India border in the westernmost region of Tripura (Fig. 1). The city has expanded rapidly and dynamically without adequate planning and control due to swift socio-economic changes (Reji *et al.*, 2025).

The latest official data on registered vehicles in Agartala is not readily available. Although vehicle numbers increased from about 3,000 in 1972 to nearly 150,000 by 2012, around 90,000 vehicles enter and exit the city daily (Down To Earth, 2025). Unfortunately there is no consolidated vehicle data for the AMC area as vehicle records are maintained at the district level, not disaggregated by municipal boundaries, limiting precise urban transport analysis. Agartala has medium-city traffic characteristics, including heterogeneous traffic, limited road capacity, and a high dependence on auto-rickshaws and two-wheelers. The coexistence of slow- and fast-moving vehicles on constrained road networks frequently adds to traffic congestion, delays, and reduced travel efficiency.

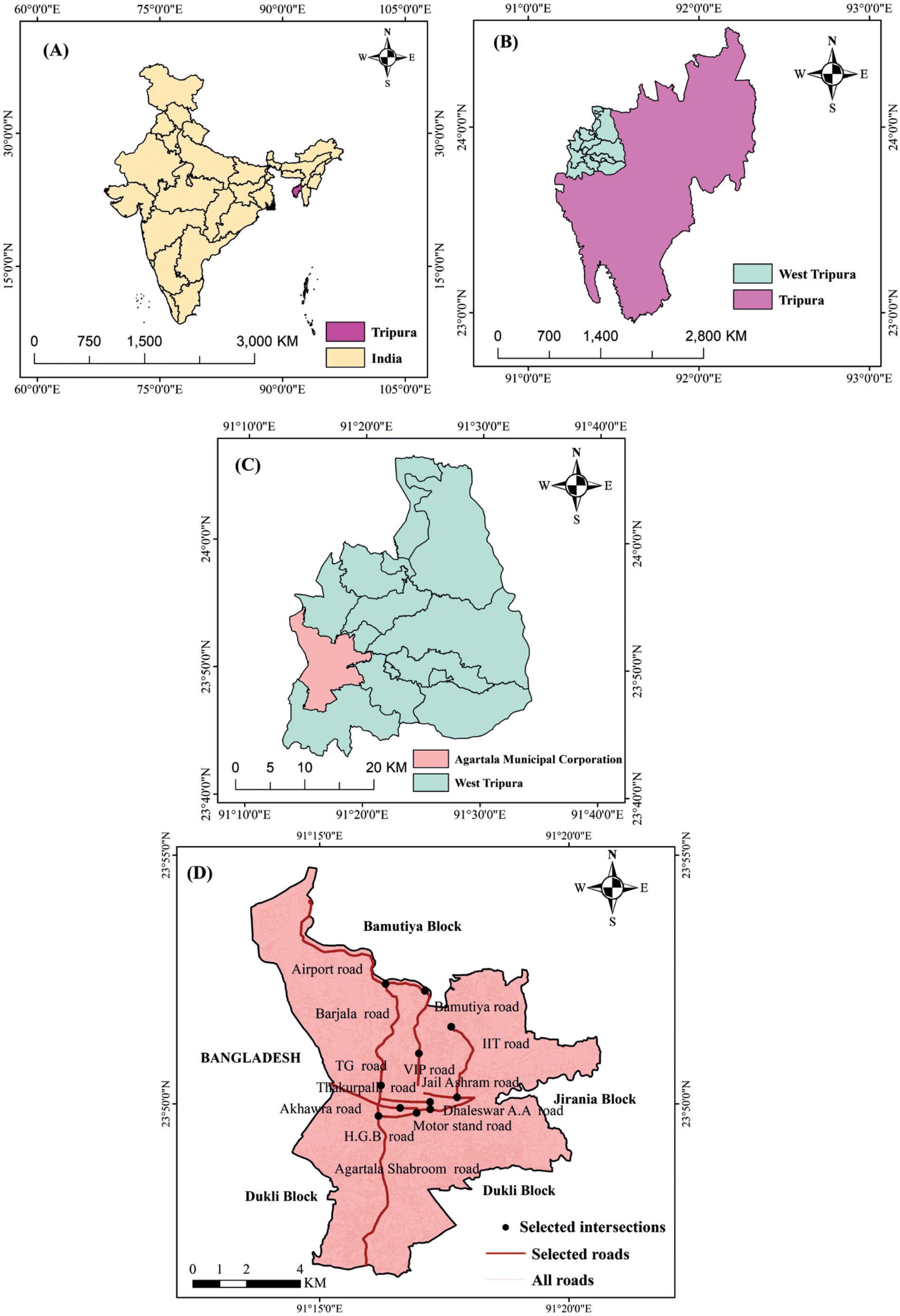

Fig. 1: Location map of the study area

Source: AMC

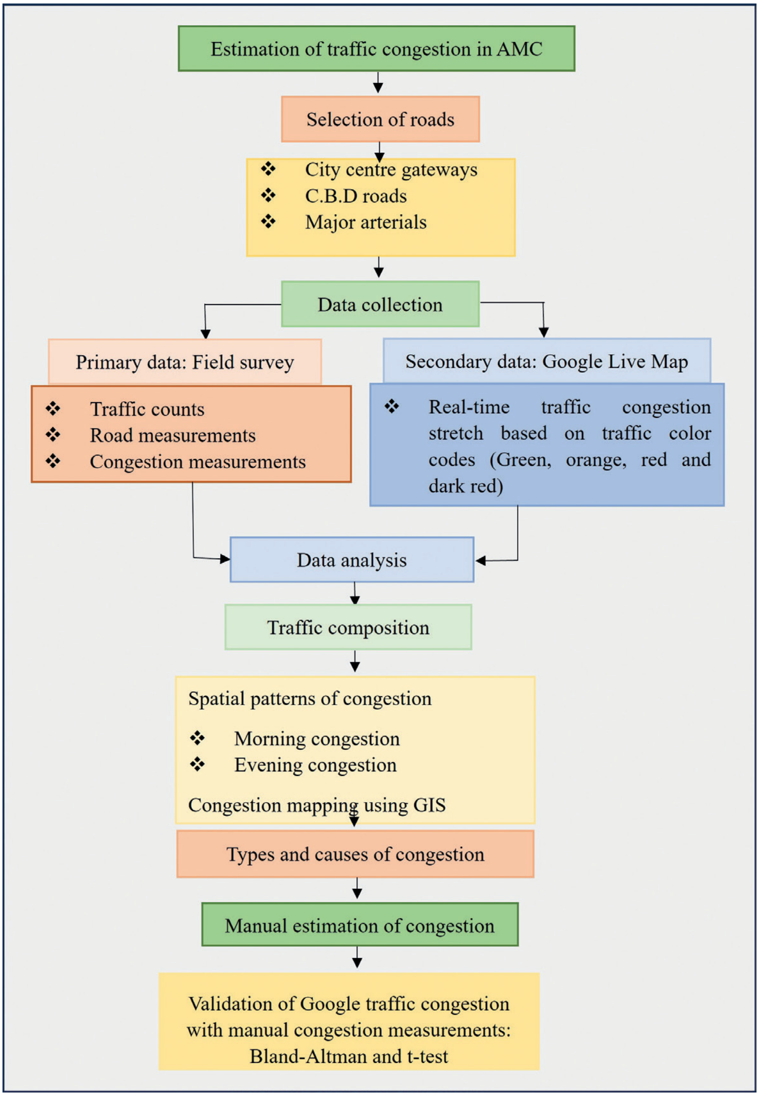

Fig. 2: Methodological flow chart

Materials and methodology

Estimation of congestion stretch within the AMC is the major objective of the paper. For this study, thirteen roads were selected, and these were categorized based on their functional roles into three main types: city centre gateways, C.B.D. roads, and major east-west/north-south arterials. City centre gateways are critical connectors linking the central part of Agartala to its periphery. These roads serve as vital gateways to the main city, facilitating movement from external regions into the urban core. However, they face physical, operational, and traffic signaling bottlenecks. Key roads in this category include the Akhaura road, which connects Bangladesh to Agartala's central city; the

Agartala-Sabroom road, linking the southern point of Tripura- Sabroom to Agartala; Dhaleswar A.A. road, which connects Agartala city to Chandrapur; and the Airport road, which links the city to Narsingarh, including its airport. C.B.D. roads are situated within the city's Central Business District (C.B.D.) and are characterized by heavy traffic and high activity. These roads include the H.G.B. road and the Motor Stand Road, which are integral to city's busiest commercial zones. Major east-west/north-south arterials are roads with significant traffic flow, serving as essential links between C.B.D. roads and other areas. These roads facilitate the movement of vehicles and goods across the city but face issues such as high traffic volume, operational inefficiencies, and physical bottlenecks. This category includes the T.G. road, VIP road, Jail Ashram road, Thakur Palli road, ITI road, Bamutiya, and Barjala road.

The data for this study were obtained from both primary and secondary sources. Fig. 2 shows a detailed methodological flow chart of the study. Primary data were collected through a traffic survey. Manual traffic counts were recorded using tally sheet method for 1-hour duration at 10-minute intervals on weekdays and an average of three were considered for analysis. The peak hours of 9:30–11:00 AM and 5:30–7:30 PM were selected as they corresponded to the major commuting periods in Agartala. The morning peak coincides with school opening hours, office start times, and commercial activities, while the evening peak reflects office closing hours, school dispersal, and increased shopping and social travel. These time-windows consistently exhibit higher traffic volumes and congestion levels on urban roads in Agartala, making them appropriate for capturing peak-period traffic conditions.

Secondary data were sourced from Google Live Maps, which provided real-time information on congested stretches of road. The Google map facilitated the identification and quantification of congested stretches in real time. It is crucial that the Google maps do not directly provide traffic data. Instead, traffic conditions for each road segment were gathered by observing the traffic colour on the map that are automatically generated from real-time traffic speed and density. Green indicated no traffic, orange represented moderate traffic, red indicated heavy traffic and dark red signified very heavy traffic congestion. Using the Google Traffic Layer, data has been collected for average weekdays in the morning and evening peak hours. Congestion levels have been assessed for each road segment based on the observed colour codes. For each road, traffic conditions have been recorded for five weekdays (Monday to Friday), for one hour during the morning peak and one hour during the evening peak, and the average congestion level has been calculated for both time periods.

The research relied on extensive field surveys to assess congestion patterns along thirteen designated roads within the AMC area. Multiple site visits were conducted to analyze traffic congestion dynamics. The total length of the selected roads were measured using Google Earth. On-site measurements were conducted to ascertain the width of the road, the width of the carriageway, and the length of footpaths with the help of 100-meter measuring tape and laser distance meter. Through Google Live Map and field survey, the length of congested stretches along each of the thirteen roads were calculated, and mapped using ArcGIS 10.3.1 software. This map provides visual insights into congestion patterns across the studied road network. Measuring tape and handheld GPS were used to measure the congestion stretch along each road and category-wise vehicles occupying the road during the congested period were counted. The following equation was used to find out the area of congestion:

Congested area per km^2 = Congested Road length × congested road width

To compare the differences between manually measured congestion and congestion estimated using Google Live tracking, the t-test and the Bland-Altman plot were employed.

Results and discussion

Traffic volume and composition

Traffic composition refers to the different types of vehicles that are moving on a particular road at a particular time. Understanding traffic composition is crucial for determining road pressure and identifying the busiest routes within a city. Fig. 3 shows the direction-wise peak hour traffic on the selected roads of AMC. It is evident that the highest vehicular traffic in Agartala is observed along H.G.B. road in the up direction, with approximately 3,096 vehicles, followed by Motor Stand road (up: 2,835 vehicles) and Agartala-Sabroom road (down: 2,835 vehicles). Significant traffic volumes are also noted on H.G.B. road (down: 2,884 vehicles), Agartala-Sabroom road (up: 2,866 vehicles), VIP road (up: 2,598; down: 2,403), Akhaura road (up: 2,301), T.G. road (down: 2,248; up: 1,901), and Dhaleswar A.A. road (down: 2,199). These roads connect critical urban functions, including markets, schools, administrative centres, hospitals, and workplaces, resulting in heavy congestion. Barjala road, ITI road, Bamutiya road, and Airport road witness comparatively lower traffic due to their limited connectivity and functional significance.

Two-wheelers dominate the traffic composition across all roads, with the highest numbers on Motor Stand road, VIP road, Agartala-Sabroom road, and H.G.B. road. These vehicles are preferred for their efficiency in navigating congested routes, especially in commercial zones. However, they are often identified as a significant contributor to traffic congestion. Auto-rickshaws are most prevalent on VIP road, Motor Stand road, and Agartala-Sabroom road, where established auto routes support their movement. Similarly, *Totos*- the low-cost electric rickshaw used for short-distance transport- are concentrated on H.G.B. road, Agartala-Sabroom road, and Motor Stand road, while their presence is minimal on Barjala, Bamutiya, and ITI roads. Private cars are more common on VIP road, Agartala-Sabroom road, and H.G.B. road, reflecting their connection to administrative and service hubs, whereas residential roads like Barjala, ITI, and Jail Ashram roads report lower car traffic. Cycles are widespread, particularly on T.G. road, Dhaleswar A.A. road, and H.G.B. road, where mixed land use dominates. Bus services are limited within the city due to its small spatial extent but operate inter-city routes on major roads like Agartala-Sabroom road and Motor Stand road, linking national highways. Roads like H.G.B. road, Agartala-Sabroom road, and Motor Stand road emerge as the busiest due to their strategic importance, while peripheral roads experience lower traffic. These patterns highlight how land use and road connectivity influence traffic

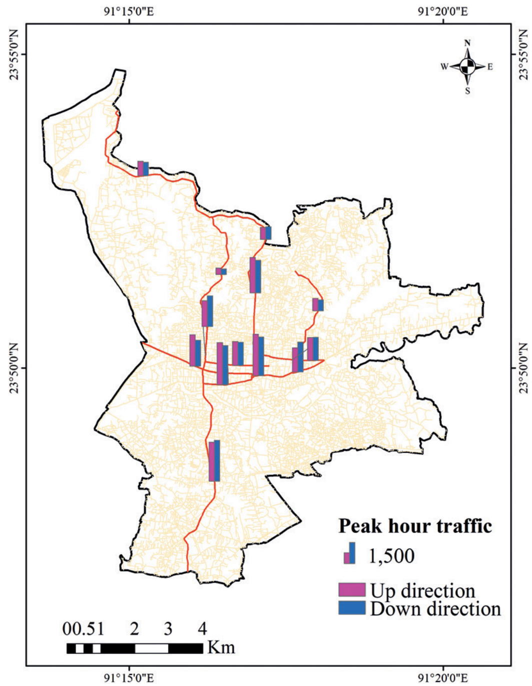

Fig. 3: Direction-wise peak hour traffic volume

distribution, offering insights for effective traffic management.

Spatial patterns of congestion (morning vs evening)

The congested stretches have been divided into four congestion types viz. high, moderate, low and free from congestion. It is evident from Fig. 4 (A) that H.G.B. road, Motor Stand road, Agartala-Sabroom road, Akhaura road, Thakur Palli road, Dhaleswar A.A. road and T.G. road, are highly congested during morning peak time. Freight movement and other transport services in cities occurs during peak hours. These being the main roads connecting to the administrative, commercial, and business hub of the city are most frequently used during office hours leading to high frequency of mixed traffic with different vehicular speeds operating along them, together with lack of parking space and hawkers occupying a portion of the available road space. Like many other cities in India, many roads in Agartala lack proper footpaths that ensure the Right of Way (ROW) for pedestrians. Available footpaths are frequently obstructed by hawkers, especially along H.G.B. road, compelling pedestrians to walk on the road carriageway. This situation contributes to congestion, as it increases the number of people using the roads meant for vehicles. VIP road, Jail Ashram road are moderately congested roads while Airport road, Barjala road, Bamutiya road and ITI road have low levels of congestion.

It is clear from Table 1 that Motor Stand road has the highest congestion stretch, about 40%, where the total road length is about 0.4 km. The high congestion stretch on H.G.B. road is about 36.7% during the morning peak hour owing to the varied land use pattern along it, followed by Dhaleswar A.A. road, Thakur Palli road, Akhaura road, T.G. road, Jail Ashram road, Agartala-Sabroom road and VIP road, with the congestion stretch ranging between 12% to 22% of the total road length. Contrarily, Airport road with 83.1%, Bamutiya road 73.6%, Barjala road 71% and ITI road 55.5% stretch is free from congestion.

From Fig. 4 (A and B), it is seen that H.G.B. road, Motor Stand road, Thakur Palli road, Dhaleswar A.A. road, Akhaura road, T.G. road and Jail Ashram road are very congested even during evening peak hours because of illegal parking along these roads, reducing the total width of free-flow traffic. Another reason is that Agartala city primarily consists of two-lane roads, many of which are separated by lane markings or rubber road separators. During peak hours, when vehicle

Table 1: Congestion stretches on an average weekday (morning peak hour)

Road	Length (km)	% congestion stretch			
		High	Moderate	Low	Free flow
Akhaura road	3.3	15.4	23.2	26.7	34.8
Agartala-Sabroom road	5.9	12.6	24.3	28.1	35.0
Dhaleswar A.A. road	1.6	21.9	23.1	23.4	31.6
Airport road	8	1.9	6.0	9.0	83.1
H.G.B. road	1.8	36.7	33.9	29.4	-
Motor Stand road	0.4	40.0	35.0	25.0	-
T.G. road	1.8	15.0	21.4	24.7	38.9
VIP road	3.9	12.1	17.4	23.0	47.6
Jail Ashram road	1.7	15.0	18.2	28.8	37.9
Thakur Palli road	1.7	17.9	27.7	23.8	30.7
ITI road	3.2	9.3	14.4	20.7	55.5
Bamutiya road	7	3.6	7.9	15.0	73.6
Barjala road	4.2	3.2	9.5	16.3	71.0

Source: Google map and primary survey

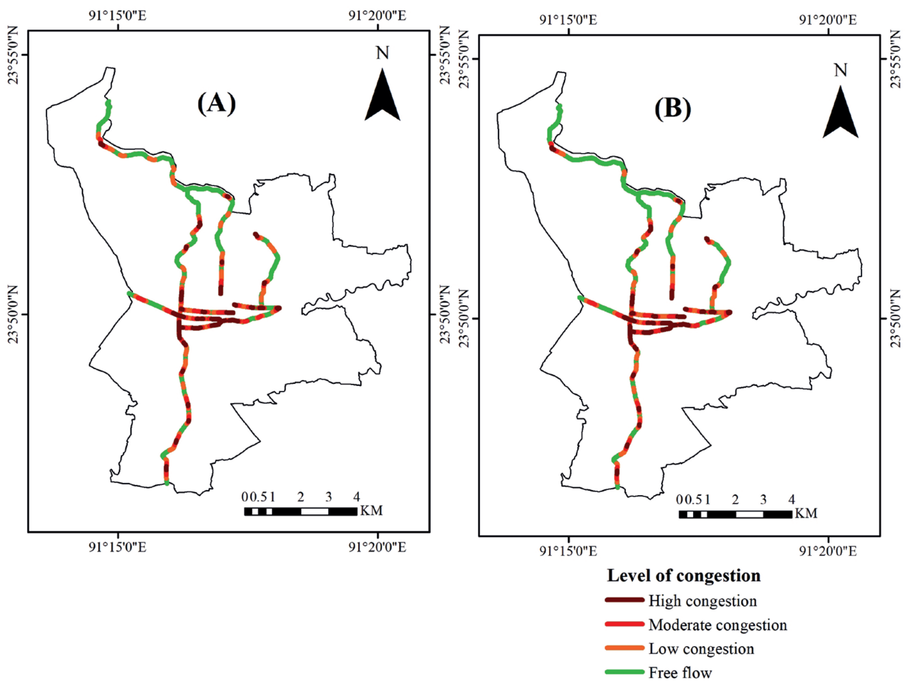

Fig. 4: (A) Morning peak hour congestion (B) Evening peak hour congestion

Table 2: Congestion stretches on an average weekday (evening peak hour)

Road	Length (km)	Average % congestion stretches (evening peak)			
		High	Moderate	Low	Free flow
Akhaura road	3.3	13.7	21.3	27.3	37.8
Agartala-Sabroom road	5.9	13.5	24.2	27.1	35.2
Dhaleswar A.A road	1.6	22.8	26.3	29.1	21.9
Airport road	8	0.5	3.6	8.2	87.7
H.G.B. road	1.8	37.5	36.1	26.4	-
Motor stand	0.4	43.0	33.0	24.0	-
T.G. road	1.8	17.2	25.8	29.2	27.8
VIP road	3.9	11.2	17.6	19.7	51.5
Jail Ashram road	1.7	15.5	20.8	30.9	32.8
Thakur Palli road	1.7	18.3	27.1	28.2	26.4
ITI road	3.2	4.7	12.3	15.6	67.3
Bamutiya road	7	1.8	3.9	14.7	79.6
Barjala road	4.2	2.5	9.6	14.2	73.7

Source: Google map and primary survey

movement is heavy, maintaining traffic within the correct lanes becomes challenging. This difficulty in managing traffic flow leads to congestion, as the limited road space is unable to accommodate the high volume of vehicles. Airport road, Barjala road, Bamutiya road, ITI road, VIP road have noteworthy free-flow stretches during evening peak time.

Table 2 shows that Motor Stand and H.G.B. road exhibit the highest congestion, occupying 43% and 37.5% of the total road length, respectively, during evening peak hours. Dhaleswar A. A. road follows with 22.8% congestion, Thakur Palli road (18.3%) and T.G. road (17.2%). Moderate congestion is observed in Jail Ashram road (15.5%), Akhaura road (13.7%), Agartala-Sabroom road (13.5%), and VIP road (11.2%). Airport road had a high free flow of about 87.7% with only 0.5% congestion, followed by Bamutiya road (79.6%, 1.8%), Barjala road (73.7%, 2.5%), and ITI road (67.3%, 4.7%).

Types and causes of congestion

In AMC area, traffic congestion is broadly classified into three types. Congestion due to physical or operational bottlenecks, network control congestion and occasional congestion. Congestion due to physical or operational bottlenecks occurs when physical constraints such as reduced road space, inadequate parking facilities leading to illegal roadside parking, and the presence of multiple vehicle types with varying speeds on the same routes, restrict smooth traffic flow. Network control congestion, on the other hand, arises due to traffic management measures such as traffic signals, which have increased waiting times at intersections. This results in vehicles becoming stagnant for a few minutes at each junction, a phenomenon particularly noticeable within the municipal limits. Additionally, occasional congestion occurs due to special cases such as accidents, rallies, meetings, or large gatherings during

Table 3: Locations and types of traffic congestion in selected roads

Road	Location	Type	Stretch (in m)
Akhaura road	Orient Chowmuhani	Occasional	80
	IGM Crossing	Network control congestion	80
	RMS Chowmuhani	Physical/ operational bottleneck	50
	Fire service	Network control congestion	120
Agartala-Sabroom road	Battala	Physical/ operational bottleneck	80
	Johar bridge	Physical/ operational bottleneck	130
	Nagerjala bus stand	Network control congestion	120
	Bordowali-Battala flyover	Physical/ operational bottleneck	210
	Near Ram Thakur College	Physical/ operational bottleneck	176
Dhaleswer A.A. road	Motor Stand	Physical/ operational	130
	Math Chowmuhani	Traffic signaling waiting point	130
Airport road	Near Albert Ekka park	Occasional	5
	Near Durjoy Nagar school	Physical/ operational	80
	Usha bazaar	Physical/ operational	60
	Near Airport	Physical/ operational	40
H.G.B. road	Battala	Physical/ operational	130
	Paradise Crossing	Traffic signaling waiting point	120
	Kaman Chowmuhani	Physical/ operational	125
Motor Stand road	Kaman Chowmuhani	Physical/operational	120
	Motor Stand	Physical/operational	153
T.G. road	Battala	Physical/operational	92
	Near Fire Service	Traffic signaling waiting point	110
	Durga Chowmuhani	Traffic signaling waiting point	115
VIP road	North Gate	Traffic signaling waiting point	90
	Lake Chowmuhani	Physical/ operational	76
	Near Nehru park	Traffic signaling waiting point	111
Jail Ashram road	Near Uma Maheswari kali temple	Physical/operational	110
	Ashram Chowmuhani	Traffic signaling waiting point	140
Thakur Palli road	Near Women's College	Physical/operational	110
	Ganaraj Chowmuhani	Traffic signaling waiting point	98
ITI road	GB Bazaar	Physical/operational	117
	Kargil Chowmuhani	Physical/operational	80
Bamutiya road	Near BSNL Staff Quarters	Occasional	50
Barjala road	Chandankhalla Bazaar	Physical/operational	60
	Near Barjala High School	Physical/operational	80

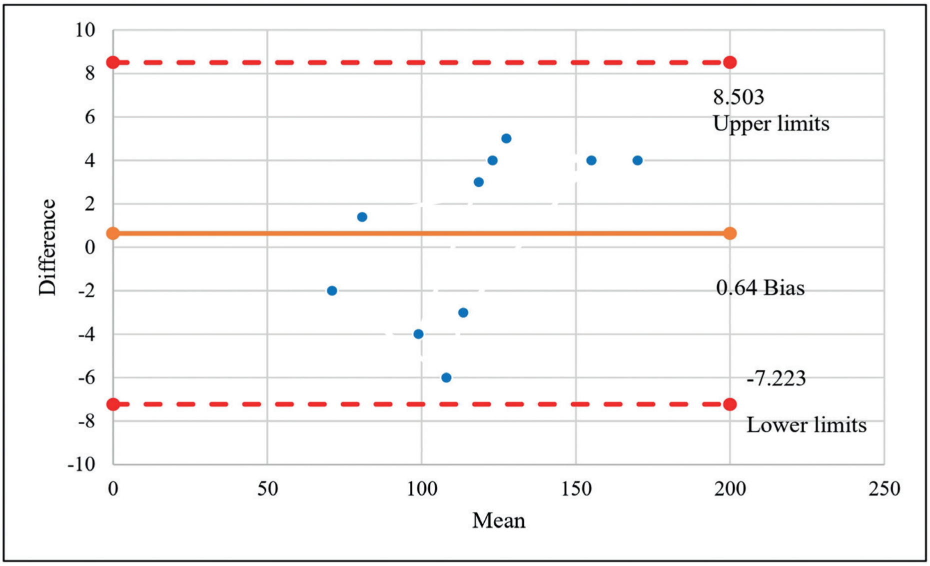

Fig. 5: Bland-Altman plot

fairs and festivals, further exacerbating traffic issues in the area.

Validation

As mentioned earlier, congestion stretches have been estimated in selected road intersections by traffic signaling waiting time congestion, and also by real-time congestion. Traffic signaling waiting times have been estimated on Akhaura road: IGM crossing, T.G. road: Durga Chowmuhani, Dhaleswar A.A. road: Math Chowmuhani, Jail Ashram road: Ashram Chowmuhani, VIP road: Near Nehru park traffic point, and Thakur Palli road: Ganaraj Chowmuhani. Real-time congestion has been estimated on Agartala-Sabroom road: Near Ram Thakur College, H.G.B. road: Kaman Chowmuhani, Motor Stand road: Motor Stand, and ITI road: GB (Table 3).

Table 4 examines the character of the congested stretches along the selected roads. The most congested area is near Ram Thakur College on Agartala-Sabroom road, with a stretch of 172 meters and 705.2 m^2 of congested area, and with a total 176 stagnant vehicles for 12 minutes due to real-time congestion. H.G.B. road near Kaman Chowmuhani experiences a congested stretch of 130 meters, with 520 m^2 congested area and 140 vehicles stagnant for 8 minutes. This is due to high traffic volume, lack of parking space, two-wheeler parking on roadsides, and footpaths occupied by hawkers. Similarly, Motor Stand road near the Motor Stand has a congested stretch of 157 meters, with 628 m^2 occupied by 126 vehicles, mainly due to its status as a traffic terminal, diverse vehicle speeds, hawkers on footpaths, and illegal parking. VIP road near Nehru Park faces congestion mainly at traffic signaling points, with a total congested stretch of 105 meters in 493.5 m^2 area, and 129 vehicles stagnant for 1 minute. T.G. road near Durga Chowmuhani experienced congestion during peak hours, with 112 meters of congested stretch, 448 m^2 area, and 115 vehicles waiting. Dhaleswar A. A. road near Math

Table 4: Manual estimation of congestion stretches in selected intersections

Intersection	Congestion duration	Congestion length (in m)	Congestion width (in m)	Congestion area (in m2)	No of vehicles stagnant
IGM Crossing	1 minute	81.4	4.10	333.74	90
Near Ram Thakur College	12 minutes	172	4.10	705.2	176
Math Chowmuhani	44 seconds	125	3.85	481.25	134
Kaman Chowmuhani	8 minutes	130	4	520	140
Motor Stand	9 minutes	157	4	628	126
Durga Chowmuhani	1 minute	112	4	448	115
Nehru park	1 minute	105	4.7	493.5	129
Ashram Chowmuhani	1 minute	70	3	210	78
Ganaraj Chowmuhani	1 minute	97	3	291	97
GB	3 minutes	120	4.7	564	107

Source: Primary survey

Table 5: Comparison of congestion stretch in selected intersections

Road	Intersection	Manual estimation congestion stretch	Congestion stretch by Google Maps
Akhaura Road	IGM Crossing	81.4	80
Agartala-Sabroom road	Near Ram Thakur College	172	176
Dhaleswar A.A. road	Math Chowmuhani	125	130
H.G.B. road	Kaman Chowmuhani	130	125
Motor Stand road	Motor Stand	157	153
T.G. Road	Durga Chowmuhani	112	115
VIP road	Nehru park	105	111
Jail Ashram road	Ashram Chowmuhani	70	72
Thakur Palli road	Ganaraj Chowmuhani	97	98
ITI road	GB	120	117

Source: Google map and primary survey

Chowmuhani has congested stretches of 125 meters, 481.25 m^2 area, and 134 vehicles stagnant for 44 seconds due to high traffic volume. Thakur Palli road near Ganaraj Chowmuhani faces congestion on weekdays, with 97 meters of congested stretch, 291 m^2 area, and 97 vehicles waiting, mainly due to varying vehicle speeds and illegal parking. Akhaura road near IGM crossing experiences congestion for 1 minute, with 81.4 meters of congested stretch, 333.74 m^2 area, and 90 vehicles waiting, linked to heavy vehicular flow and IGM hospital's emergency traffic. Jail Ashram road near Ashram Chowmuhani

Table 6: t-test to compare congestion stretch

	Manual estimation	Google Map based measurement
Mean	116.94	116.3
Variance	990.258	851.344
Observations	10	10
Pearson Correlation	0.994	
df	9	
t Stat	0.504	
P(T<=t) one-tail	0.313	
t Critical one-tail	1.833	
P(T<=t) two-tail	0.626	
t Critical two-tail	2.262	

congestion occurs due to poor management and slow-moving vehicles, with a congested stretch of 70 meters, 210 m^2 area, and 78 stagnant vehicles. ITI road near GB Bazar experiences congestion over 120 meters, with 107 vehicles stagnant, attributed to GB Bazar's influence, illegal parking, and the presence of GB Hospital.

Table 5 shows that at the intersection of IGM Crossing, Kaman Chowmuhani, Motor Stand, Ashram Chowmuhani, and GB, the manual measurements of traffic congestion slightly exceed the calculated congestion levels. Conversely, at Ram Thakur College, Math Chowmuhani, Durga Chowmuhani, Nehru Park, and Ganaraj Chowmuhani, the calculated congestion levels are higher than those measured manually. However, it's worth noting that these differences are very minor.

An attempt has been made to know the difference between manual estimation of congestion and Google map-based congestion stretch in selected intersections of Agartala city using Bland-Alman plot and t-test. The Bland-Altman plot is used to evaluate the agreement between manual estimation and Google Maps-based measurements of congestion stretches (Fig. 5). The plot reveals a small bias of 0.64, indicating that the average difference between the two methods is minimal and that there is no significant systematic error. The limits of agreement, ranging from -7.223 to 8.503, encompass most of the data points, demonstrating that the differences between the methods are generally within an acceptable range.

The standard deviation of 4.012 reflects moderate variability in measurements. Overall, the Bland-Altman analysis confirms good agreement between manual estimation and Google Maps measurements. This indicates that Google Maps can serve as a reliable and efficient alternative to manual methods for assessing congestion stretches, significantly simplifying the process of traffic analysis.

The t-test results (Table 6) show no statistically significant difference between the manual estimation of congestion stretches and the congestion measurements obtained through Google Maps. The calculated t-stat (0.504) is much smaller than the critical values for both the one-tail (1.833) and two-tail (2.262) tests, and the p-values are much greater than the standard significance level of 0.05.

Conclusion

Traffic congestion in Agartala city has emerged as a serious urban transport challenge. The analysis indicates that real-time congestion caused by physical bottlenecks is the most dominant form of congestion across the city. Motor Stand road, H.G.B. road, and Dhaleswar A.A. road experience the highest congestion levels, while Ram Thakur College on Agartala–Sabroom road, Motor Stand on Motor Stand road, and Kaman Chowmuhani on H.G.B. road are identified as the most congested intersections. These findings highlight the need for targeted traffic management and infrastructure interventions at critical corridors and junctions.

Improving public transportation can alleviate traffic congestion by increasing transportation capacity and reducing the burden on roads. Clearing footpaths, utilizing road width efficiently, and enforcing parking regulations can further ease congestion. Additionally, creating proper parking facilities can reduce congestion, pollution and enhance safety.

Competing interest

The corresponding author declares that they have no conflict of interest.

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