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RESEARCH PAPER

GIS-based Analysis of Traffic Congestion in Midnapore Municipality

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Abstract

Rapidly growing cities in developing countries like India are facing some concerns such as unplanned and unsystematic urban growth. One such impact is the problem of traffic congestion. Midnapore municipality, one of the rising cities in West Midnapore, as a result of the high growth rate of population and motorized transportation in Midnapore municipality increasing day by day along with the traffic congestion. Most of the busy traffic intersection points in Midnapore are badly affected by huge traffic congestion. Encroachment of the road by pavement dwellers and illegal car parking has reduced the widening space of the road and even improper construction of road dividers, unscientific construction of speed breaker, size and weight of the car, the problem of the traffic signalling system and traffic diversion, a large number of on-road personalized cars, two-wheelers and autos are some of the reasons behind the traffic congestion in the municipality of Midnapore. The road density is divided into five categories like very Low value of road density (0.00-995.96), Low-density value (995.97-1659.93), Medium density value (1659.94-2344.66). High-density value (2344.67-3319.87) and Very high-density value (3319.88-5291.04). Congestion causes tremendous vehicular air pollution within the municipality of Midnapore. A traffic management plan is one of the best policies for solving traffic congestion in developing cities like Midnapore municipality. In most cases the invested money is irreversible. The traffic management plan has the scope of improvement of the existing road network and system and plan proposal for new development. In this paper, the problem of traffic congestion in Midnapore town has been addressed.

Keywords: Traffic congestion; Illegal parking; Encroachment; Narrow roads; Traffic signalling system; Speed Breakers; Intersection Points; Traffic management.

1. Introduction

1.1 Background of the study

"Transportation is a measure of relations between areas and therefore an essential part of geography" [1]. The road network is playing a vital role in the development of any area. The network system of any city is just like the veins of the human body. [2], [3]. The Transportation System is a critical component of urban infrastructure and the lifeline of the city. It also displays the region's economic condition as well as the planner's dedication to their region. Efficient route planning and accessibility facilitate sustainable development. Midnapore municipality is a small town, in the state of West Bengal. The town also serves as the headquarters of the Midnapore subdivision. As per the 2011 census, the population of Midnapore Municipality is 169264 out of which 84977 are male and 84287 are female and has a population density of 9211/km^2. Midnapore has several roads and streets that provide connectivity and accessibility to the town. However, during peak hours it suffers massive congestion problems largely because of the imbalance between the carrying capacity of the roads and the number of vehicles.

The present study highlights the traffic problem at Midnapore municipality, Paschim Medinipur, West Bengal. Due to the rapid growth of the population in a few years' vehicles, accidents, and traffic jam are increased here but the new roads and the proper rules for the development of roads have not developed here for a long time [4], [5]. In this city, the footpath is mainly used for small businesses. In the main center of the city (LIC. Collectory, Main bus stop, Keranitala) a large crowd creates a traffic problem every day. In the markets, places are very conservative (Borobazar, Raja Bazar, Sepoy Bazar, Patna Bazar) but any development should not be observed here for a long time. Geographic Information System (GIS) technology is most useful in management functions and decision support systems which are more helpful in the planning process of urbanization planning [6], [7]. The various applications of GIS can be used for the identification of road network areas and change detection inroads. It can also be used to detect the distance between one place to another place. It not only detects the distance but is also used to show the shortest path between the two places. These applications of GIS can be used in traffic control.

1.2 Statement of the Problem and Literature Review

Traffic congestion occurs randomly during peak hours which may contribute to an increased occurrence of certain types of traffic incidents [8], [9]. Traffic congestion is one of the major urban problems that torment many emerging large and small towns and cities especially due to increased private transportation, improper management-affecting societies, environmental pollution, and overall, the process of development [10], [11]. Traffic congestion is another root cause in the city for slower vehicular speeds, larger trip times, and increased vehicular queuing which is responsible for a huge number of vehicular emissions [11], [12]. Midnapore has registered a growth in terms of the total number of motorized transports which has increased exponentially but the road infrastructure is not proper which in turn results in traffic congestion in the city [13], [14]. Congestion refers to deferring caused by one vehicle to another when the volume of traffic is high on a particular road [15], [16]. Traffic congestion cost involves incremental delay, vehicle operating cost (fuel and wear), pollution emissions, and stress that result from interference among vehicles in the traffic stream. More traffic congestion leads to emitting a large number of automobile pollutants in the environment of Midnapore and respondents have been suffering from various chronic diseases which might be the resultant factor because of huge emissions in the city of Midnapore. A primary survey based on traffic congestion highlights that people of Midnapore suffer mentally when they are stuck in traffic jams during their busy working hours and it means delay in reaching their working destination in proper time [11], [17]. All these factors have attracted people to congregate in this fast-growing urban area which has led to intolerable traffic congestion on the streets for the last few decades. One-lane roads, insufficient parking spaces, inefficient management, and illegal parking are a few of the reasons for traffic congestion that has caused distress to the residents, in Midnapore. Different congestion methods have been proposed and are being implemented such as road capacity expansion can alleviate congestion problems but may not be a solution that is sustainable in the long run.

1.3 Research objectives

Indian Road Congress (P-598, 1990): According to IRC Capacity Estimation is Fundamental to the Planning Designing, and Operation of Roads. Initially, tentative Road capacity sales for urban roads between junctions were recommended by the Indian Road Congress in IRC 86-1983. This Guideline is applicable for mid-block sections of urban and suburban areas. However, those are not directly relevant to the urban expressway. IRC classified the roads based on the Number of Lanes Functionality of the Road. Based on the Number of Lanes, Roads are of two types one is undivided, and the other is divided. On the other hand, functional roads classified into four categories those are 1. Arterial 2. Sub-Arterial 3. Collector Street 4. Local Street. The term Level of Service is a qualitative measure unit. According to the Indian Road Congress India has six types of LOS designs from A to F while the 'A' class provides free flow speed and better accommodation for traffic whereas the 'F' class provided heavy congelation of traffic and less traffic flow rate. The LOS is affected by uncontrolled traffic, the speed of the vehicle, roadside parking areas, road intersections, and Roadside commercial activity.

The capacity of the Indian highway is determined by various traffic flow operating situations by the use of VISSIM microscopic simulation software and compared the simulated traffic data with field traffic data and modify specific parameters (driver behaviour) which disturb the simulation result. Mainly analyze two roads, one 4 lanes, and the other 6 lanes. Data are collected from the total faced 6hr in a single day by using video method and examine it. Some researchers provided the process for capacity estimation of two-line roads under mixed traffic conditions and calculated the influencing factors that affect the capacity of the road and adjustment factors for each of these conditions proposed. The capacity of a two-line road based on these adjustment factors under heterogeneous traffic conditions is determined. Traffic Congestion and Possible Solutions a case study of Asansol. Using the survey method the movements of the vehicle from 9.30 AM to 10.30 AM comprised a total no of 3247 vehicles, standing on the different meeting points of the study area to show the volume of movements. Snapping the images at peak hour and also non-peak hour to show the comparison of different situations at different times. The main objective of this study is to find out the road network analysis in Midnapore municipality with traffic congestion analysis; road density and road network-related issues analysis using GIS application for understanding the city traffic congestion-related problems.

2. Study Area

Midnapore municipality is one of the major towns and the administrative capital of West Midnapore District. It is situated on the banks of the Kangsabati River. The Midnapore town covers an area of 18.65 km2 surrounded by the Cassai River on the south, Panchkuni 1 and Panchuni 2 G.P. on the west, Siromoni G.P. on the north and Kankabati G.P. on the east. The location of Midnapore municipality is 22°23'30" N to 22°26'30" N and 87°17'15" E to 87°20'15" E. Midnapore municipality has an area of 18.65 km2 and its elevation is 23 m (75 ft). The total population of Midnapore municipality is 169264 and the population density of the area is 9211.70 per sq. km according to the senses of 2011 (District handbook) there are few major roads which are connecting with other districts. Midnapore municipality is characterized as an important trade and communication center of West Midnapore. The district lies under the zone of influence of Calcutta City which is one of the fast-developing cities in the State. The district is dotted with many industrial units for its easy transportation linkages with other parts of the state and country. As such, Midnapore City is selected as the study area for this research.

Midnapore is notable for its contribution to the history of the Indian freedom movement since it has produced many martyrs. During the British Raj, the city became a center of revolutionary activities, such as the Santal Revolt (1766–1767) and the Chuar Rebellion (1799). The Zilla School, now known as Midnapore Collegiate School was the birthplace of many extremist activities. Teachers like Hemchandra Kanungo inspired and guided the pupils to participate in the Indian Freedom Movement. Three British District Magistrates were assassinated in succession by the revolutionaries Bimal Dasgupta, Jyothi Jibon Ghosh, and Pradyot Kumar Chakrabor were some of the young, Nirmal Jibon Ghosh. Khudiram Bose and Satyendranath Basu were some of the young men who laid down their lives for the freedom of India. Kazi Nazrul Islam attended political meetings in Midnapore in the 1920s. Raja Narendra Lal Khan, ruler of Narajole, who donated his palace for Midnapore's first college for women, had been implicated, (although it turned out to be false) for planting a bomb. However, the most significant archaeological site in the region is the bustling port of Tamralipta near present-day Tamluk, a site noted in the travelogues of Faxian and Xuanzang. Later Chaitanya passed through the area on his way from Puri to Varanasi as documented in the Chaitanya Charitamrita. After the fall of the last independent Hindu dynasty of Kalinga-Utkala, Gajapati Mukunda Deva in the 16th century, this region came under one of the five Sarkars of Mughalbandi Odisha Jaleswar Sarkar which was ruled by the Subehdar of Odisha. Khudiram Bose was born in Habibpur in 1889 and studied at Midnapore Collegiate School up to the eight standards. He was first caught by a policeman for distributing seditious leaflets in Midnapore in 1906. The Mallick Zamindars also ruled over an extensively large area during British rule. They also built the Jagannath Temple of Midnapore. The Zamindari house declined after independence but the palace can still be seen at Mallick Chowk at Barabazaar. The palace also has a Durga manch in it and a Krishna temple in it (Figure 1).

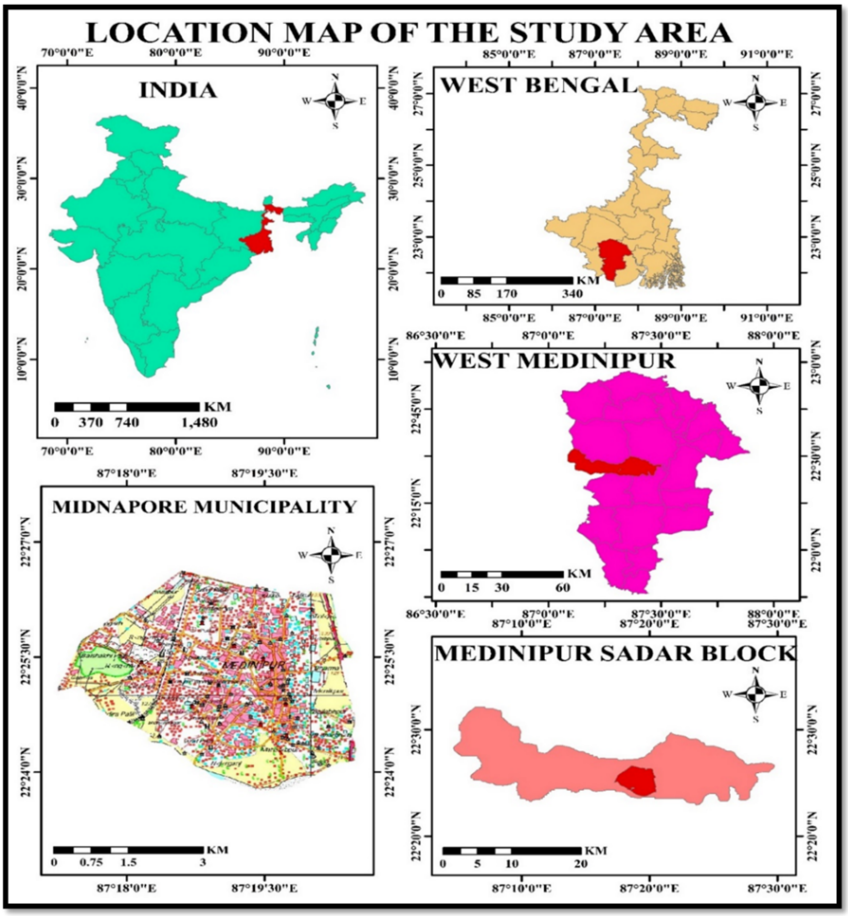

Figure 1: *Locational map of this study area.*

3. Materials and Methods

3.1 Data source

In this study area, various datasets are used,are modified in the various processes. Data are shown in the following steps. Gramin GPS 12 has been used to obtain the geographical coordinates of the observed field location and tape used during field survey. QGIS 3.22.2 is used for geo-referencing of scanned maps, and digitization, and Arc Map 10.8 is used for making geo-database of road networks, and producing maps. The kernel density tool is used for the determination of the kernel density map and the network analysis tool is used to create the new geo-database and prepare the connectivity map. Microsoft Office Excel and Word calculate the density and draw the graph (Table 1).

Table 1: *The details about data sources used in this study*

Data Types	Format	Resolution	Path/Row	Spatial data for map	Time periods	Data Source
Sentinel-2B	GeoTIFF	10m	139/044	LULC	10-03-2022	(https://www.usgs.gov.in)
SRTM DEM	GeoTIFF	30m	139/044	Slope, Aspect	2014	(https://www.usgs.gov.in)
Soil of West Bengal	SHP	1:50,000		Soil Map		(https://icar.org.in)
Street Map	KML			Road map (Types)	2022	Google Earth Pro

3.2 Geometric Survey

Traffic congestion, unnecessary delay, and accident at road intersections are partially affected by the geometric elements at intersections [11], [13]. The geometric elements affect the free flow at intersections. The basic geometric requirements of the intersection at grade are given below. i) at the intersection the area of conflict should be as small as possible. ii) The relative speed and particularly the angle of approach of the vehicle should be small. iii) Adequate visibility should be available for vehicles approaching the intersection. iv) Geometric features like turning radius and width of pavement should be adequately provided.

3.3 Traffic volume survey

Traffic volume can be defined as the number of vehicles passing through a section of road per unit of time. Study observed the traffic volume during the peak hours [14]. Traffic volume reflects the importance of road for improvement and expunction. Vehicle speed calculates: - To calculate vehicle speed.

$$V = \left(\frac{D}{1.47T}\right) \tag{1}$$

where V = spot speed (m/h), D = length (feet), and T = elapsed time (seconds).

3.4 Classification

Supervised classification is performed to the satellite image of the study area, the use of prior knowledge available from the topographic, true color map, and field surveys (ground truthing) while training the computer by way of assigning "training areas about different features that are to be classified by the computer Using their feature signatures given by the analyst, each pixel with similar characteristic signatures is grouped and assigned to respective classes [6], [18].

3.5 Digitization

Digitizing is the process of encoding the geographic features in digital form as x, and y coordinates. It was carried out to create spatial data from existing maps and documents. In the present work, the geo-referenced raster true color map and municipality map of Midnapore municipality are digitized using Arc Map 10.8. This type of digitization is called "on-screen digitization". Road networks of the study area are digitized as line features [19]. Major traffic conjunction roads are also digitized as line features. Traffic locations are digitized as point features Ward boundary of the study area is digitized as polygon features. The above spatial data are organized in a geodatabase and feature class.

3.6 Assigning Attributes

All vector data (line, polygon, and point features) will contain separate attribute tables. The dent location attribute table contains year wise number of fatal accidents, the road network attribute table shows widthwise different roads and the Major traffic conjunction roads attribute table contains to be of vehicles (up and down data of bus, auto, lorry, car, bike, rickshaw, and cycle) on working and non-working days of the study area.

3.7 Kernel Density Estimation

Most of the conventional indicators and spatial interpolation techniques use Euclidean distances for space characterization. In the urban environment, these approaches do not take into account the road network constraint and its influence on the location of spatial events. KDE is a statistical process used for spatial smoothing and/or spatial interpolation [15], [20]. KDE is a well-known tool in urban studies. Like these recent works, this paper examines a network-oriented approach to density, but still operates over the 2D space, like the conventional Kernel Density [21], [22].

Kernel Density Estimation (KDE) is an important approach to analyze the spatial distribution of point features and linear features over 2-D planar space [23], [24]. Some network-based KDE methods have been developed in recent years, which focus on estimating the density distribution of point events over 1-D network space. However, the existing KDE methods are not appropriate for analyzing the distribution characteristics of certain kinds of features or events, such as traffic jams [25]. These events occur and distribute in 1-D road network space, and present a continuous linear distribution along the network. Firstly analyze the density distribution of each linear feature along networks, then estimate the density distribution for the whole network space in terms of the network distance and network topology. In the case study, apply the KDE-L analyzes the space–time dynamics of vehicles' pick-up events, with a real road network [26]. Vehicles' pick-up events are defined and extracted as linear events (LE) in this paper. First conduct aspace–time statistics of pick-up LE in different temporal granularities. Then analyses the space–time density distribution of the pick-up events in the road network using the KDE-L, and uncover some dynamic patterns of people's activities and traffic condition. Kernel Density Estimation shows the smoothing effect and can be applied only on the Points and Polylines. The density is detected in dark red colour for the traffic location.

$$f(x) = \frac{1}{nh}\sum_{i=1}^{n} K\left\{\left(x - \frac{Xi}{h}\right)\right\} \tag{2}$$

Where $f(x)$ is the density estimation at the location x, h is the bandwidth, n number of points within the bandwidth/the number of observations, K is the Karnal function $(x - Xi)$ represents the Euclidian distance between each point i and the location where the density estimator is worked out.

This paper first abstracts the pick-up events in reality into linear features in network space then proposes the NKDE-L by improving and extending the standard planar KDE to network space. The road network in this paper is a network topology consisting of nodes and links with length attributes. The complex road elements inside a road (such as road centreline, and road outline) are not considered. Representation of LE in network space. To introduce the proposed NKDE-L method, this paper first analyses the density distribution of each linear feature along networks then estimates the density distribution for the whole network space in terms of the network distance and network topology. Considering the inhomogeneous characteristic and topological direction of the network, the NKDE-L improves and extends the standard planar KDE in two aspects:

3.7.1 Measurement of Connectivity

Network analysis is an important aspect of transport geography because it involves the description of the disposition of nodes and their relationships and the line or linkage of distribution. It gives measures of accessibility and connectivity and also allows comparisons to be made between regional networks within a country and between other countries. "The degree of connection between all vertices is defined as the connectivity of the networks". The greater the degree of connectivity within a transportation network, the more efficient that system be. Researchers have studied the structure of transportation networks and developed several descriptive indices for measuring the connectivity of networks, i.e., beta, gamma, and alpha indices. Connectivity measures evaluate the intensity of connections between road segments. Connectivity refers to the directness of travel between destinations. A well-connected network has many short links, numerous intersections, and minimal dead-ends providing continuous, direct routes to destinations. Various indices used for evaluating the connectivity pattern of road transport networks are Alpha Index, Beta Index, Gamma Index, Eta Index, and Grid Tree Pattern Index.

A. Alpha Index

One of the most useful measures of the connectivity of a network, particularly a fairly complex network, is the alpha index (α). Alpha index (α) is the ratio of an actual number of circuits to the maximum number of circuits in the network. It ranges from 0 (no circuits) to 1 (completely interconnected network) [27].

$$\alpha = \frac{e - v + 1}{2v - 5} \tag{3}$$

Where, e - number of edges in the network; v - number of vertices in the network.

The alpha index gives the range values from 0 to 1 which is from 0 to 100 percent. If the index is multiplied by 100 this will convert it into a percentage, thereby giving the number of fundamental circuits as a percentage of the maximum number possible [28]. The higher the index, the greater the degree of connectivity in the network.

B. Beta Index

The beta index is a very simple measurement of connectivity, which can be found by dividing the total number of arcs in a network by the total number of nodes [29], [30]. Beta index (β) is the number of links per node. Greater the value of (β), the greater the connectivity. As transport networks develop and become more efficient, the value of (β) should rise.

$$\beta = e/v \tag{4}$$

The beta index ranges from 0.0 for networks, which consist just of nodes with no arcs, through 1.0 and greater where networks are well connected. β value for tree types of structures and disconnected networks would always be less than 1. It would take zero values when there are no edges in the network. β value for any network structure with one circuit would always be equal to 1. β value exceeds 1 for a complicated network structure having more than one circuit.

C. Gamma Index

The gamma index (γ) is the actual number of edges to the maximum possible number of edges. The connectivity of the network is evaluated in terms of the degree to which the network deviates from an unconnected graph and approximates a maximally connected one. It ranges from 0 (no connections between nodes) to 1 (the maximum number of connections, with direct links between all the nodes) [31].

$$\gamma = \frac{e}{3(v - 2)} \tag{5}$$

D. Eta Index

Eta index (η) indicates the average length per link. Adding new nodes will cause a decrease in the eta index as the average length per link declines [32].

$$\eta = M/e \tag{6}$$

M - total network length in km. This index is useful in examining the utility of a given transport network. Kansky has used this index in analyzing the transport network data for several countries [33].

E. Grid tree pattern index

Grid Tree Pattern (GTP) index is a measure for identifying the pattern of the network, varying from 0 in the case of a tree pattern to 1 in the case of a grid pattern [34].

$$\frac{e - v + 1}{(\sqrt{v} - 1)^2} \tag{7}$$

Attempted to explore the spatial variation of the road network structure of Midnapore city with the help of graph connectivity measures along with road density [35].

4. Results and discussion

Traffic congestion is a situation on road networks when the physical use of the road by vehicles increases. It occurs when the road network is no longer capable of accommodating the volume of movements that are used by them and it is characterized by slow speed, long trip timing, and high vehicular queuing.

i. Increasing growing population: In Midnapore cities rapidly growing population by birth and migration faces unexpected congestion on the road. Better facilities like communication system, medical facilities, and educational institution lead to heavy traffic.

ii. Passage of heavy vehicles on narrow roads: Traffic congestion is also caused due to the passage of heavy vehicles through narrow roads in most cases huge traffic is stuck for a longer duration. Generally, this happens due to the diversion of traffic.

iii. Improper planning: In Midnapore city is one of the oldest cities in West Bengal, so proper planning was not done at that time and in modern times growing urbanization leads to the worst. Improper planning of city development Plan has its long-term city development planning. But that planning is not proper. Most of the time it is seen that some illegally ceased roadside land, but due to the vague development plan these kinds of movements are going in vain.

Table 2: *Location of traffic congestion zone.*

SL.NO	Major Traffic Junctions point	Latitude	Longitude
1	LIC	22°25’32"	87°19’11"
2	Keranitala	22°25’15"	87°18’57"
3	Raja Bazar	22°25’25"	87°19’36"
4	Bara Bazar	22°24’50"	87°19’41"
5	Patna Bazar	22°24’35"	87°19’06"
6	Sypoi Bazar	22°25’48"	87°19’22"
7	Collcttorate	22°25’34"	87°19’06"

iv. Illegal parking: The main cause of illegal parking is insufficient parking space available for parking vehicles. Illegal parking is one of the main causes of traffic congestion in Midnapore city. Illegal parking’s are mostly done in front of the bus stop, petrol pumps, footpaths, etc. Due to this traffic flow is interrupted and slows down the speed of vehicles until the wrongly parked vehicles are removed. Random parking on the main road is common habit of drivers and riders, causing unexpected congestion at any time.

v. Irregular public transport: Irregularity of public transport courage people to depend on private vehicles.

vi. Increasing rent: Increasing rent within a short distance of public transport is one of the reasons to depend on private vehicles.

vii. Festival and Occasional congestion: Another cause for congestion is during festival seasons due to heavy traffic the traffic is diverted through narrow roads and causes traffic congestion.

viii. Improper Lane management: Lane management is an important fact in managing the traffic in Midnapore city. Many types of vehicles try to overtake the vehicles even on a single undivided road. This is the main reason that the city roads are unequipped with the lane dividers which divide the lane into incoming and outing traffic.

ix. City planning: New quarters in the city were built without planning. New quarters are just appended to old quarters without constructing roads serve these new areas. New quarters depend totally on the roads of older quarters. Because of this reason, there is heavy traffic on this road. It can be said that Koya is a randomly built city, there is no serious city planning.

x. Forced occupiers the retailer forcedly set up their business along the main city road or bus road and pavements causing the narrowing of the road.

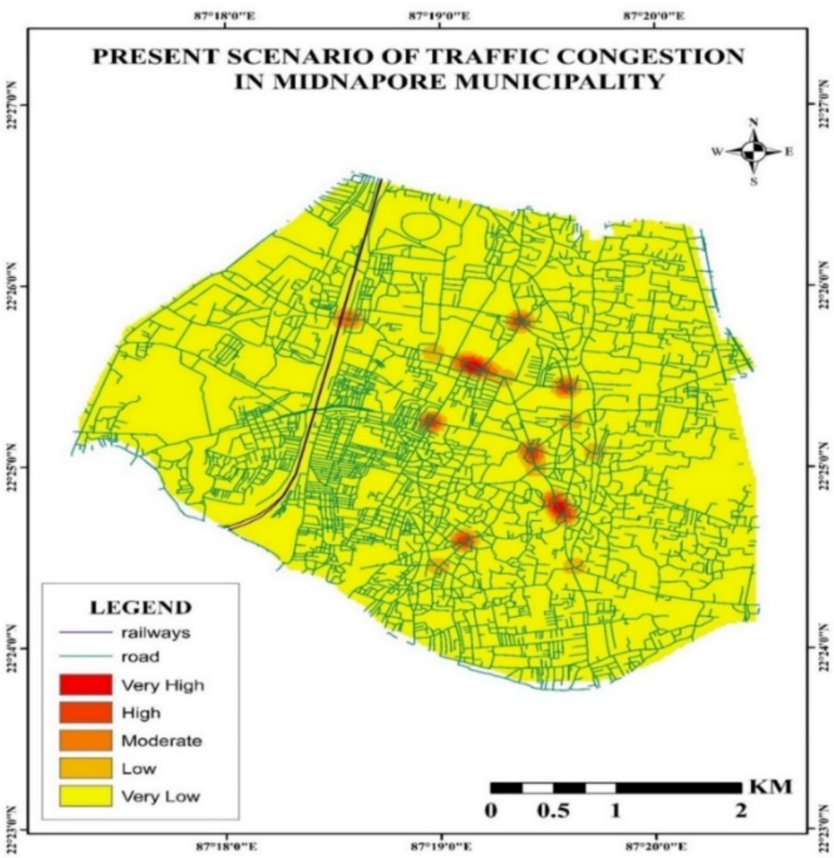

Figure 2: *Traffic congestion area of Midnapore Municipality.*

4.1 Zone of traffic congestion

In the main center of the city (LIC. Collectory, Keranitala) a large crowd creates a traffic problem every day (Table 2). In the markets places are very conservative (Borobazar, Raja Bazar, Sepoy Bazar, Patna Bazar) but any development should not be observed here for a long time (Figure 2).

4.2 Transportation of road network

The street pattern of Midnapore municipality is mainly mixed type. This area's main road is NH 14 and NH 116. At a particular time specifically during office hours, the roads become inaccessible due to high numbers of vehicles. Some places are highly populated but their number of road very less. The Midnapore municipality area is situated in a main bus stop, Railway Station, Main Road, and Road, etc. A general layout of the network database is in Figure 3 and the map is shown. Some important parts of the selected study city have huge congestion and mostly in the Bara Bazar, LIC and others bus stand areas, where mainly Toto, rickshaw, cycle, and bikes are the reason for traffic congestion.

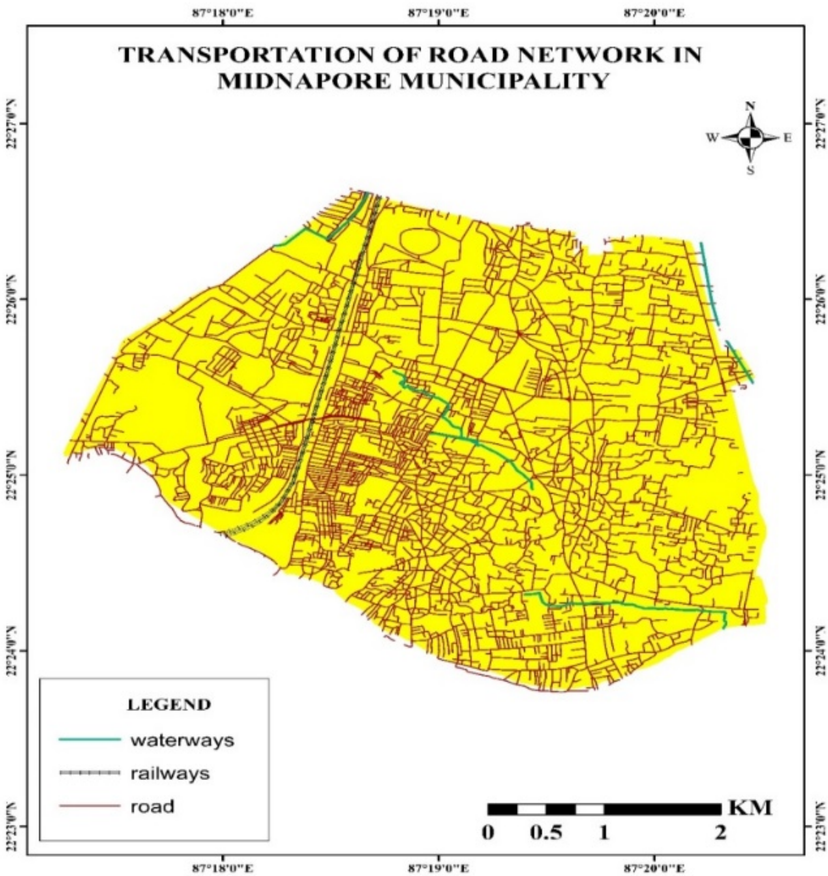

Figure 3: *Transportation of road network.*

4.3 Road junction

A network is a system of interconnected elements such as lines Edge) and connecting junctions (points) which represent every A network is a system of interconnected elements such as lines (Edge) and connecting junctions (Nodes or points) which represent every possible route from one Junction to another Junction. From a feature class, a network dataset is created but it is restricted that from only one feature class can create only one Network Dataset. The ArcGIS Network Analyst extension allows you to build a network dataset and perform analyses on a network dataset. To create a Network Dataset, right-click on Feature Dataset on which you want to perform a Network Analysis. Then select New Tab and from the new tab select Network Dataset. Once the Network Dataset has been created then open Are Map to perform Network Analysis (Figure 4).

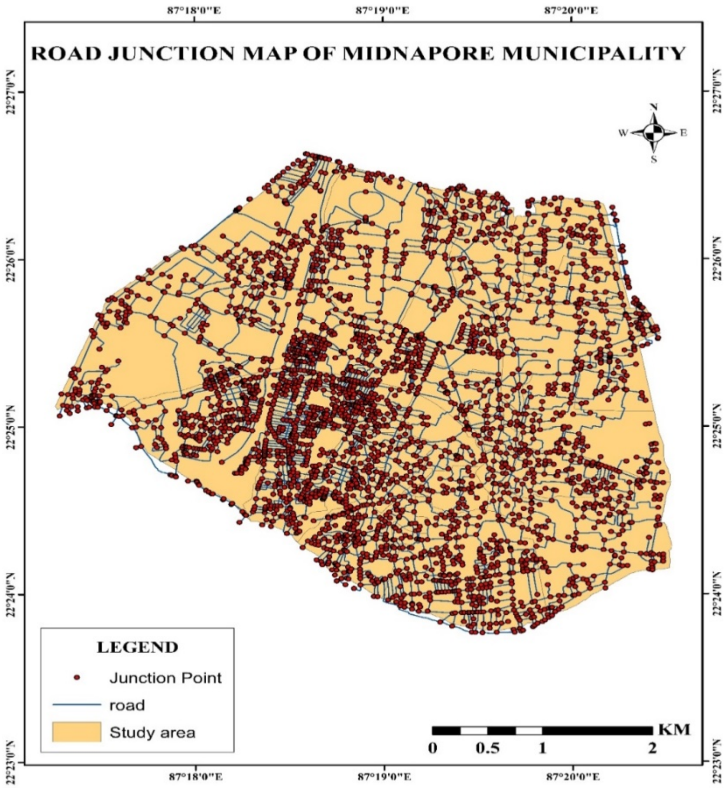

Figure 4: *Road junction map.*

4.4 Road density

The Road Network density is used to measure Network Development and traffic management. It is defined as the length of the road per square meter area of the network. Road density is one of the parameters for planning the enhancement activities of the study area (Figure 5). The Road Density of the Midnapore Municipality area is calculated by using the equation given below. The study area was classified into five classes based on road density, Very Low value of road density (0.00–995.96), Low-density value (995.97–1659.93), Medium density value (1659.94–2344.66). High-density value (2344.67–3319.87) and Very high-density value (3319.88–5291.04). Road density is more important for understanding the traffic congestion and its helps for the traffic problem solving. The Midnapore city have huge traffic congested area where mostly traffic congestion occurring for bike, cycle and rickshaw.

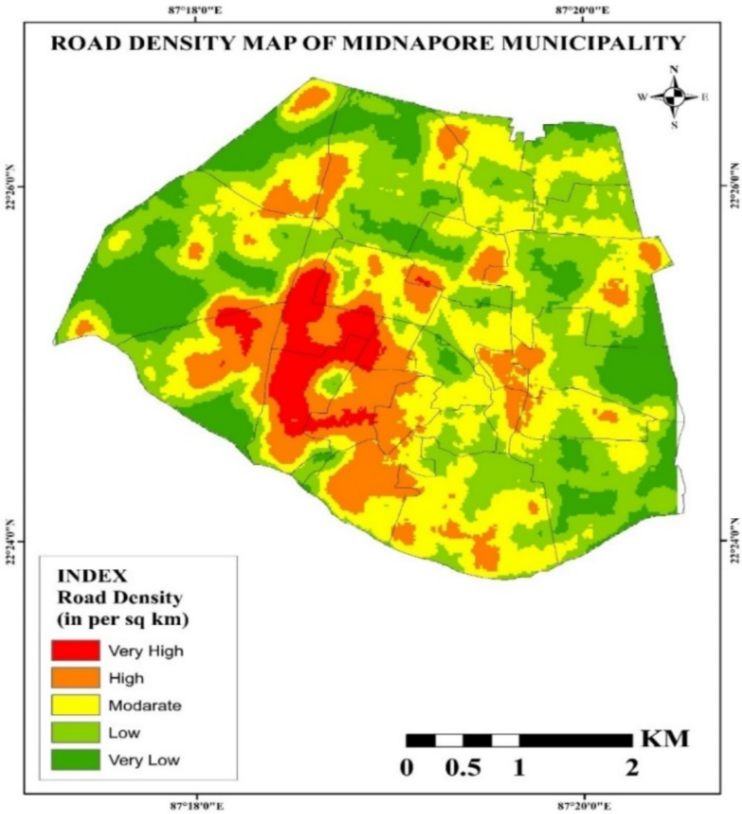

Figure 5: *Road density map.*

4.5 Road width

Road width plays an important role in the transport system. The running of the vehicle is generally controlled by road width. Loaded vehicles mainly pass through roads with more than 25 feet, in width. The study area was classified into five classes based on road width (feet), there are 0–10, 10–15, 15–20, 20–25, 25–30 (Figure 6).

4.6 Road types

The speed of transport depends on the type of road. The main road like NH 14 and NH 116 road is made by Bitumen Pitch. Some road is made of Concrete, some road are made of Moram, and some roads made by earthen roads in different wards and different villages in the Midnapore municipality Area (Figure 7).

4.7 Population density

The population density was calculated by ward-wise total Population and area covered by each ward. Very High population density was found in Midnapore (ward no 11) and Low population density was found in so many wards, in some ward names is (25, 3, 9, 18, 17). The study area

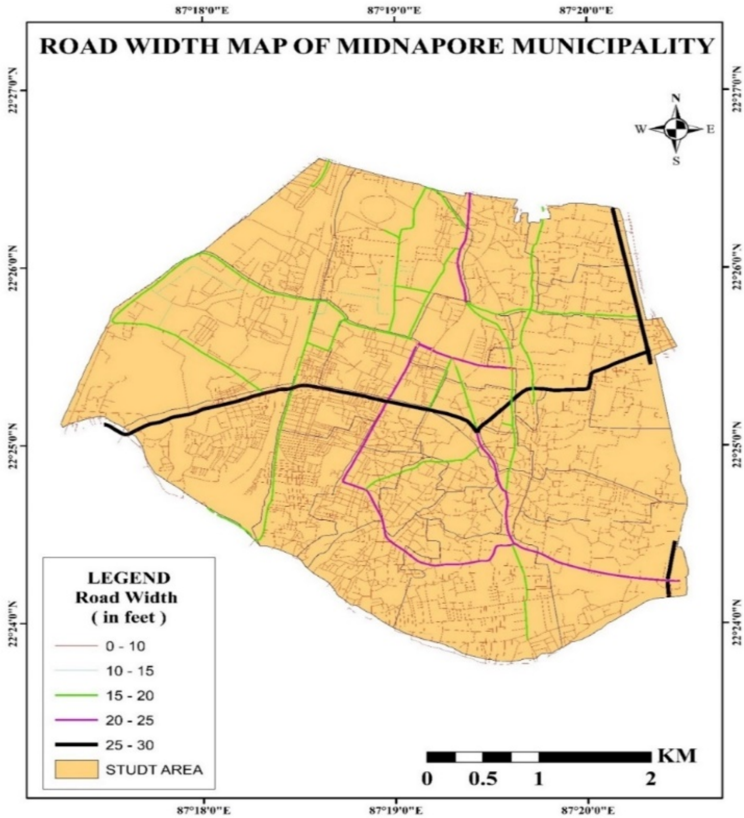

Figure 6: *Road width map.*

was classified into five classes based on population density. Very Low value of population density (3119.20–5840.28), Low population density value (5840.29–9562.33), Medium population density value (9562.34–13264.99). High population density value (13265.00–23050.09) and Very high population density value (23050.10–30248.26) (Figure 8).

4.8 *Kernel density*

Kernel Density Estimation method was used for calculating the traffic congestion zone within the study area. This method divided the whole study area into default number cells and applied a circular neighborhood around each zone. Since it is a spatial analysis method, it measures cell densities in a raster by using a sample of known points. This process can be expressed as a bivariate probability density function, a kernel function looks like a "bump," cantering at a known location and tapering off to 0 over a defined bandwidth or window area. The output of the KDE method is presented in a raster format consisting of a grid of cells. The two main parameters that influence the KDE method are cell size and bandwidth. The choice of bandwidth is quite subjective [21]. Kernel Density Estimation shows the smoothing effect and can be applied only on the Points and Polylines. In this study, results found out the kernel density in the year 2022 (Figure 9). The density is detected in dark red color for the traffic congestion zone. Kernel density is high observed in the central, south and western part of the study area. Mainly in the city centre areas.

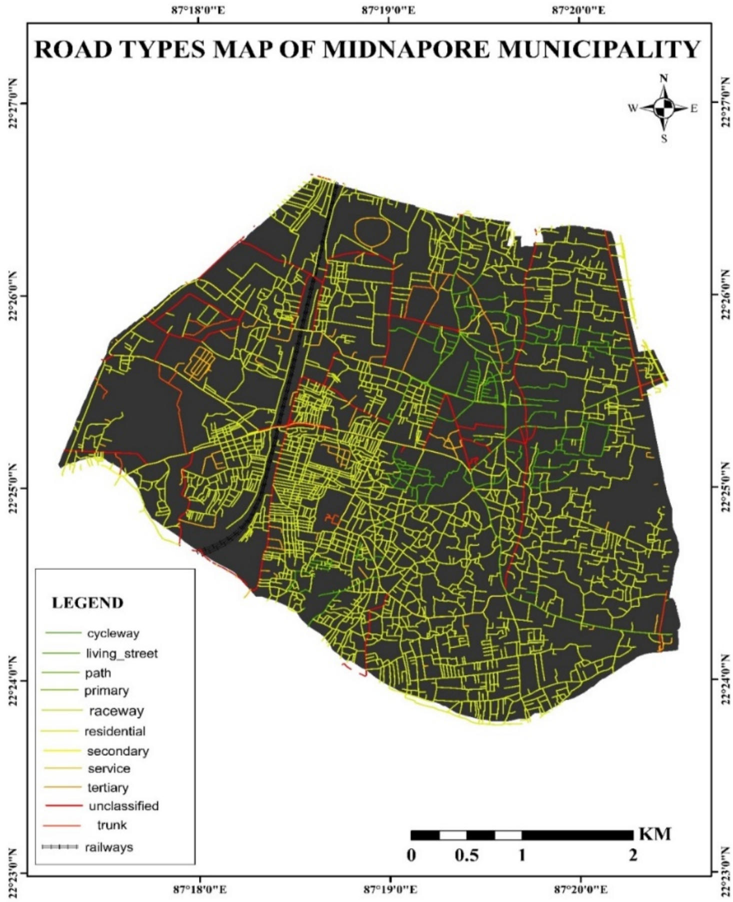

Figure 7: *Road types map.*

4.9 Measurement of connectivity

The connectivity of a network may be defined as the degree of completeness of the links between nodes. When a network is abstracted as a set of edges that are related to the set of vertices (nodes), a fundamental question is the degree to which all pairs of vertices are interconnected. Network analysis is an important aspect of transport geography because it involves the description of the disposition of nodes and their relationships and the line or linkage of distribution. It gives measures of accessibility and connectivity and also allows comparisons to be made between regional networks within a country and between other countries (Table 3). "The degree of connection between all vertices is defined as the connectivity of the networks". The greater the degree of connectivity within a transportation network, the more efficient with that system be. Kansky has studied the structure of transportation networks, and developed several descriptive indices for measuring the connectivity of networks, beta, gamma, and alpha indices [33].

To generate connectivity indices such as Alpha, Beta, Gamma, GTP, and Eta, several nodes and links within each zone were required (Figure 10). Network dataset analyst of ArcGIS 10.8 was used to generate nodes and edges, from which connectivity indices were evaluated for all zonal tracts. Descriptive statistics of various connectivity indices are listed in Table 3.

Table 3: *Calculation of different connectivity index*

Name of the road	Nodes (V)	Edges (e)	Length (km)	Alpha Index	Beta Index	Gamma Index	Eta Index	GTP Index
NH14	2	1	0.023152	0	0.5	0	0.023152	0
NH14	7	7	0.029198	0.1111	0	0.47	0.004171	0.3692
NH14	2	1	0.05616	0	0.5	0	0.05615	0
NH14	2	1	0.057181	0	0.5	0	0.057181	0
NH14	3	2	0.111975	0	0.66	0.66	0.059875	0
NH14	2	1	0.112056	0	0.5	0	0.112056	0
NH14	5	4	0.164734	0	0.8	0.44	0.041184	0
NH116	6	5	0.244709	0	0.83	0.42	0.048942	0
NH14	2	1	0.42275	0	0.5	0	0.42275	0

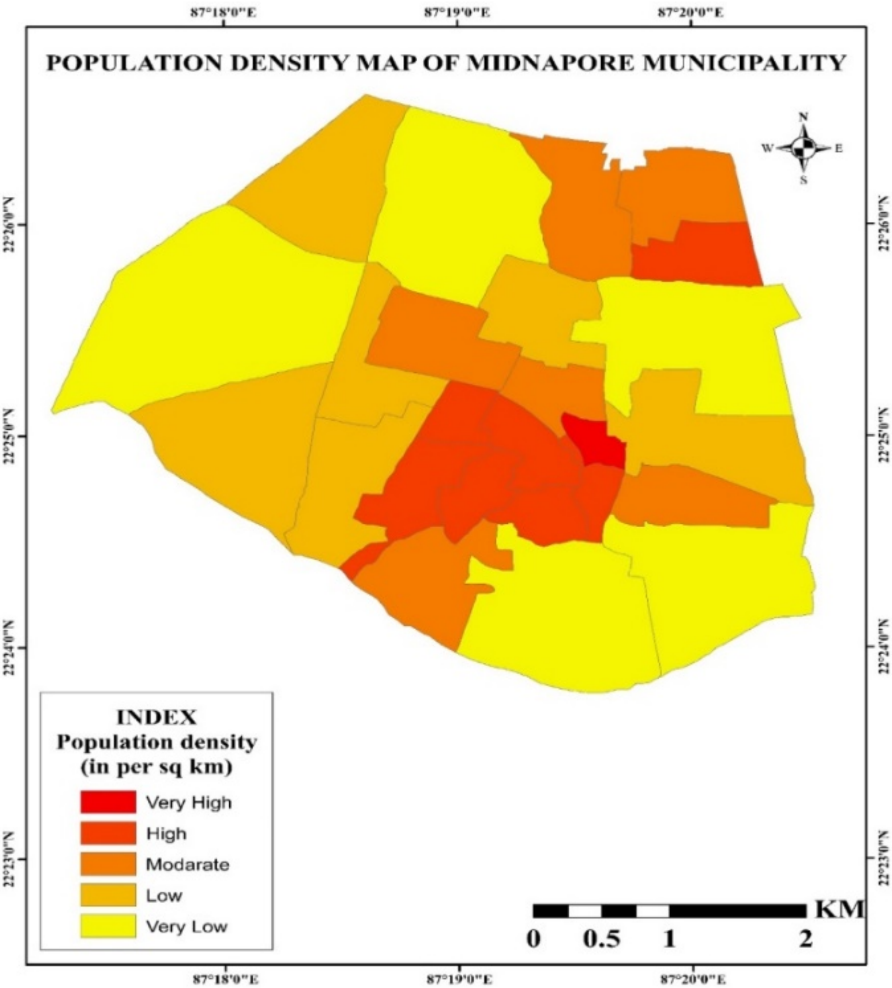

Figure 8: *Road types map.*

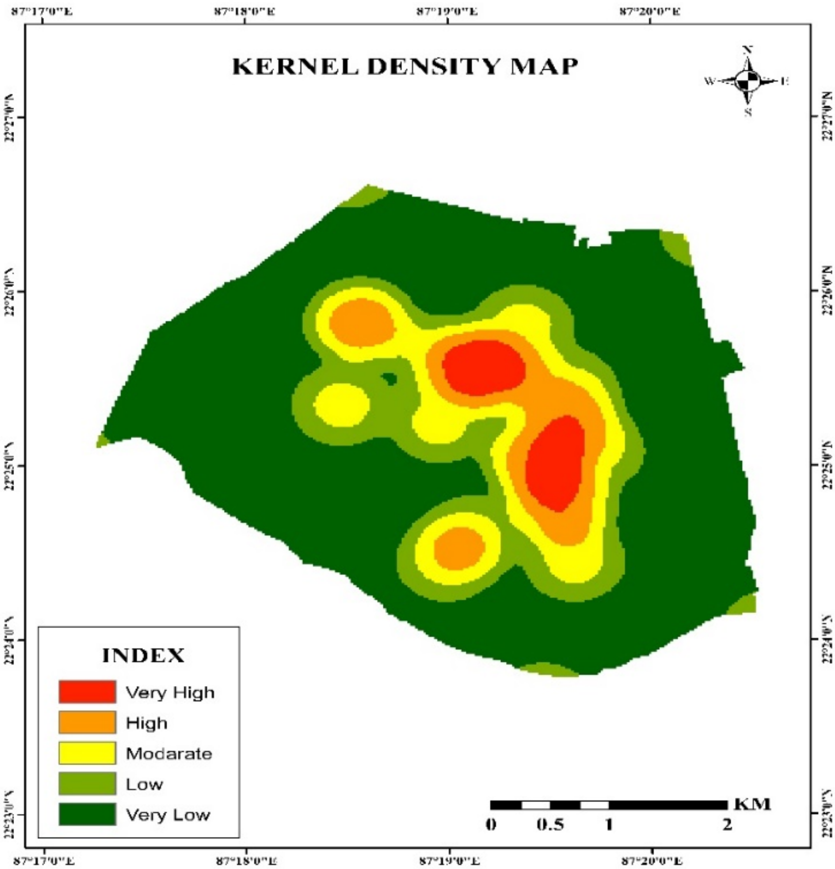

Figure 9: *Kernel density map.*

4.10 Possible solution for traffic congestion reduction

4.10.1 Transportation planning

Transportation plays a great role in the planning of any city. It is also an important factor for socio-economic development. Various transportation planning observed below, which are famous all over the world among them some management techniques were used for the transport planning of the Midnapore municipality. Traffic congestion can be reduced by either reducing traffic flow or increasing road capacity. Because the reasons for this kind of problem are local, not generic, therefore, solutions are also specific to this case only and can't be applied to other cases in different cities, below are the solutions proposed by this paper:

1. Traffic calming: Measures that seek to reduce the speed of vehicles in urban areas, such as speed bumpers and street narrowing. For residential streets, the goal is to make their use by car drivers unattractive because of the obstacles; for thoroughfares, the objective is to reduce the average speeds. The measures indicate the need for much greater attention to street design and layout.

2. Car sharing: Car sharing is another process for the management of traffic; People should use carpooling and vehicle sharing to decrease the number of vehicles on the road. Everyone should avoid the unnecessary collection of vehicles.

3. Set up office complex: Like Salt Lake town of Kolkata, a vacant area should be arranged to set up an office complex to reduce movement from here to there. In addition, the existing office

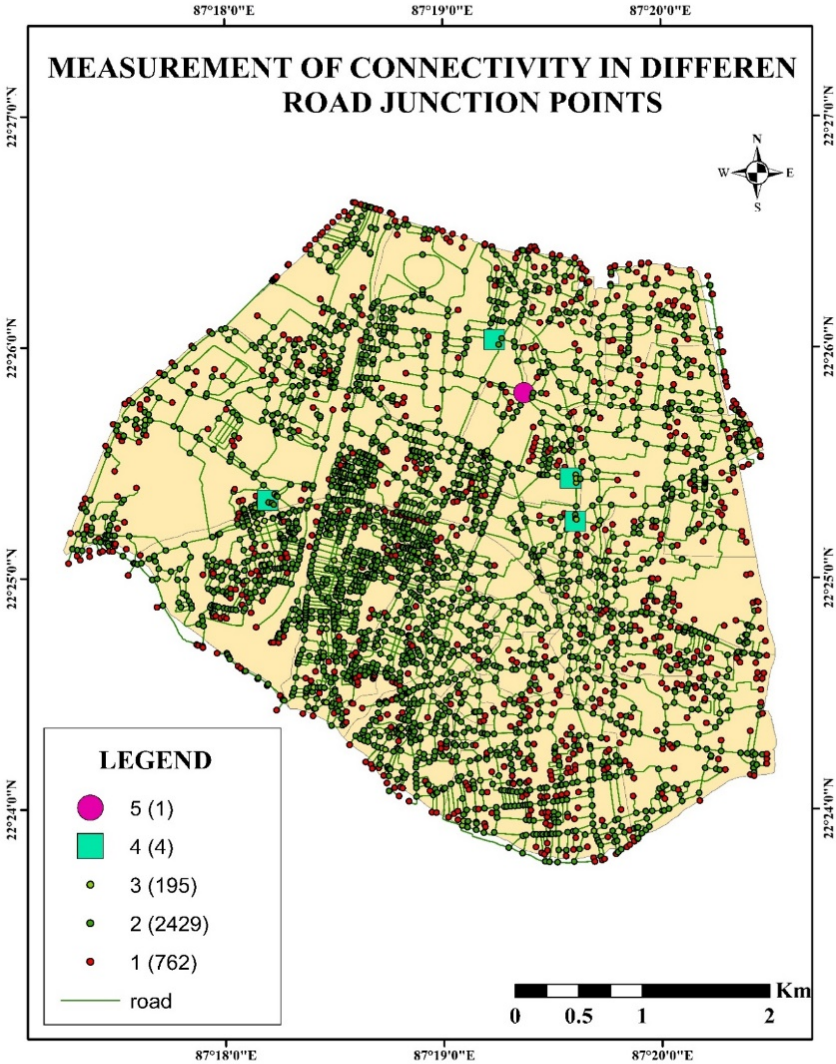

Figure 10: *Connectivity map.*

along the main road where gatherings occurred can be shifted to the vacant area or separate the commercial region and residential region in the city.

4. City service bus: Start the available city service bus system where all the personal cars or vehicles park in a specific place and provide a ticket to individual cars or vehicle owners which can use for bus journeys in the same fair from the parking land within the city area.

5. Proper parking system: Set up new toto, auto, two whaler and privet car parking centers arrange a vacant place that will give the solution of random parking and parking congestion.

6. Minimum bus stoppage: Maximum one or two stoppages should be along the main bus route to avoid congestion.

7. Street usage capacity: This scheme may be used to improve the road network capacity and to reduce road conflicts on the selected routes in the city. Bus lanes can also be used successfully which will lead to improving in the level of service and will reduce congestion.

4.10.2 Intelligent Vehicles, Highways and Smart Traffic System

A. Smart traffic control system (IoT integrated AI System) The drawback of having a predefined time-based signaling system in many cities is that the traffic management system functions irrespective of traffic flow. And the responsive smart traffic control systems act according to real-time traffic conditions. Below mentioned are the components of the smart traffic control system–

i. A central control system: The central control system acts as a base of a traffic control system. This system is integrated with traffic lights, signals, cameras, and queue detectors. The AI-based system can analyze real-time data by collecting information from the computer vision-enabled 3d AI cameras and queue detectors. The AI system helps in passing on a piece of optimized information to control the functioning of the traffic lights and signals for the free flow of traffic.

ii. Smart signal lights: Smart traffic lights and signals reduce the inefficiencies in traffic congestion and idle time at intersections. The intelligent lights can manage the queue and clear the traffic irrespective of the predefined timing system.

iii. Intelligent cameras and queue systems: The cameras and queue system updates information to the control system about real-time traffic condition. And the control system enacts this real-time information to clear the overcrowding traffic and helps in reducing pollution.

B. Smart traffic monitoring system

i. AI-integrated big data tools and IoT-enabled intelligent communication systems are integral parts of smart traffic monitoring systems. These systems replace traditional ticketing systems with automation by providing advanced assistance through IoT-enabled communications. The tech components that define the smart traffic monitoring system are traffic lights, smart roads, public transportation, smart parking, and geospatial traffic guidance system. Services by integrating sensors, vehicle-mounted information systems, and private individual vehicle tracking devices for tracing commuter locations.

ii. Smart roads and smart highways are developing tech applications of AI. The roads and highways are equipped with sensors that monitor vehicle speed and inform the vehicle owners through vehicle-mounted information systems regarding speed over the limit, penalties, and information regarding overhead traffic. Smart parking enables access to information through an app or mobile application regarding vacant parking lots at a particular location for better assistance.

iii. Geospatial traffic guidance system is an integration of GIS, GPS, and radiofrequency devices. It provides 3d visualization of real-time geographical data based on the position of a physical object. GPS is currently used to detect the best routes to reach particular destinations within less time based on the traffic in all possible pathways. Geospatial technology can advance this system by providing guidance, possible upcoming obstacles, and traffic inflows from various routes and their respective queue length.

4.10.3 Planning of new road

The most congested sections are LIC, Collectory, Keranitala, Borobazar, Raja Bazar, Sepoy Bazar, and Patna Bazar. Ashok Nagar and the bus stop have also become severely congested. To handle the problem in this place need to constrict new flyover and clear the footpath, proper parking system and lean management system are needed to solve the problem.

i. One-way routes: Medinipur city has a two-way transport route system, creating congestion. If started one-way route system like LIC more to Medinipur Head Post office road for going and main road for coming may give a greater relief from congestion.

ii. Construct a short flyover: Construct the short flyover at the meeting road for all ages pedestrians lighting the congestion. The antigenic level crossing creates a gate problem for regular traffic. Construct a short flyover should be provided here to solve the problem.

iii. Control traffic flow: The heavy traffic road should be managed by the control of traffic flow. In those busiest roads just like GT road the speed of the vehicle should be limited.

iv. The bus stand is situated in the center point of the city, which makes a problem for the regular traffic in this area if the bus stand sifted in any free space or clears the footpath near the bus stop then the traffic of this area should be managed.

v. Selective transport mode: Selective transport mode at office hour time the slow-motion transport media like rickshaws, the cycle should not be permitted, only buses, cars, and bikes are allowed along the main city road.

vi. Lean management: A separate lane should be constructed beside the main road for the movement of bi-cycle, hand pulled Rickshaw, Cycle Rickshaw, Toto and Auto.

vii. Road widening: The first solution clicks to mind are the possibility of widening the road, where it is possible. The width of the station road is very small; this road width should be increased and need traffic police. viii. Heavy vehicles should be prohibited on busy roads during office hours. ix. The loading and unloading should be done outside of the main city center.

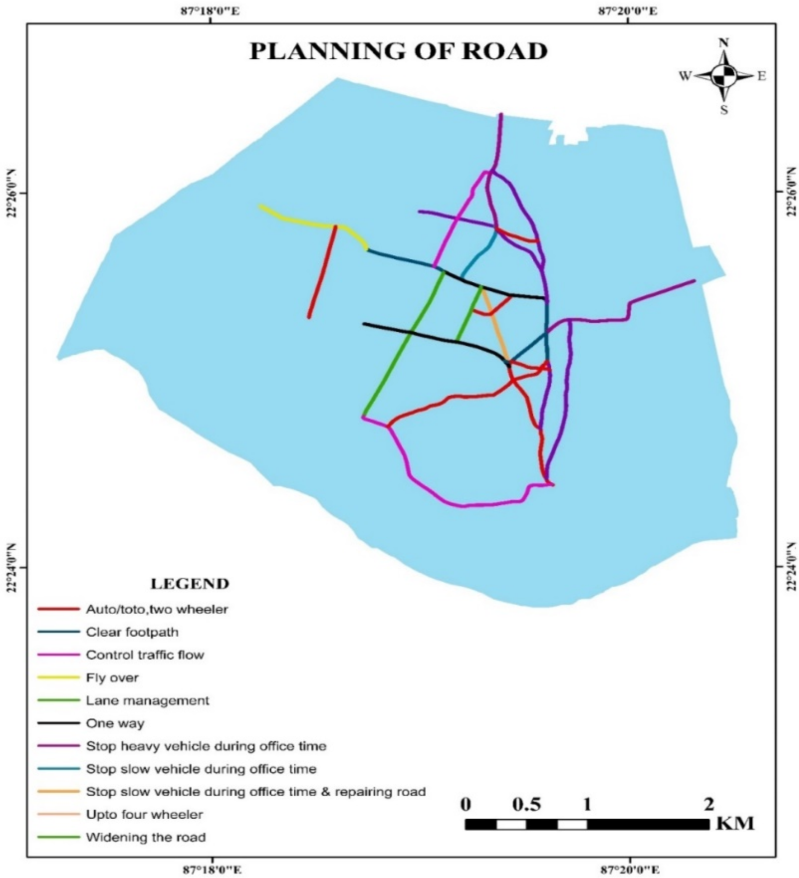

Figure 11: *Planning of new roads.*

x. The parking place should be very important for the management of traffic. The parking problem occurred all over the town. Example- Bara Bazar to Raja Bazar, Raja Bazar to collectorate, Collectorate to Jagannath Mondir via Keranitala and Battola. Vehicle parking should not allow in public place. It should be applied as a rule and regulation. Public transport is very important to the management of any area. In Midnapore city above 500 minibus is run every day for the public transport, people should use those transport facility.

xi. Clear the footpath: The enforced concentration of small shops along the footpath shorting the main road. So, clearing the footpath will give a solution. Regular monitoring by the administration will prevent such kind of occupancy (Figure 11).

Midnapore city is mostly congested due to the high population density, unplanned roads, and traffic volume. Therefore the main market, bus stand, near the educational institute, and complex areas are more congested than the other areas. Mainly narrow lane and shops near road sides are the reason for traffic congestion in Midnapore city (Appendix).

5. Limitations and recommendations

Every study or researches have more limitation. Our study has some limitations; those are Estimate road capacity only in a selected area. During the collection of data, there are many problems with the transportation system or Geographical accessibility. Another analysis method like multi-simulation is not included in this study. GIS is a powerful tool that allows updating geospatial data at any time. GIS can store, analyze and retrieve the bulk of geospatial data. Therefore, it is here recommended that the Midnapore municipality and other stakeholders can use GIS technology for road transport service.

There are many problems, one of the most important problems is the parking problem occurred all over the town example- Bara Bazar, Raja Bazar to Collectorate, and Collectorate to Jaganathmonder via Keranitala and Battola. Parking management is very much important demand for all over town. In this area some roads should be restricted in the time of pick hour. These roads are the head post office to Battola to Keranitala Road, Rangamati Road, and Vidyasagar University Road in the time of office hours (10 am to 11 am). Heavy vehicles should be prohibited and at other times they should decrease their speed. The width of the station road is very small; their road width should be increased. In the accidental zone, the arrangement of traffic police keeps the affected people and gives them first aid, and helps to send them to nearby hospitals.

6. Conclusion

Now traffic congestion became a common problem for all urban cities and also for Midnapore municipality. Everyplace in the world, the prime reason behind traffic congestion is on-street parking. The distribution of road network was used as a data source, geo-referenced, and imported into a GIS environment to determine their accessibility. Road network analysis like kernel density analysis and measurement of connectivity were done in Arc Map 10.8 software. The GIS software, Quantum GIS was used to digitize the roads from Google Earth's open street layer. The main objective of the project is to build a road network geospatial database in a GIS environment and assess their spatial arrangement in the study area and produce a proper traffic management plan. The Road Density of the Midnapore Municipality area is calculated by using the equation given below. The study area was classified into five classes based on road density, Very Low value of road density (0.00-995.96), Low-density value (995.97-1659.93), Medium density value (1659.94-2344.66). High-density value (2344.67-3319.87) and Very high-density value (3319.88-5291.04). Road density is more important for understanding traffic congestion and it helps for traffic problem solving. The midnapore city has a huge traffic congested area where mostly traffic congestion occurs for bikes, cycles, and rickshaws.

To analyze all the projects, the population of this area increased a large amount in the upcoming year. To solve this problem one suitable zone is evaluated here by the use of GIS. GIS is also key to evaluating urban facilities and utilities and planning by providing spatial resolution information. The whole study has been done with the help of field surveys and GIS data. All parameters and methodologies have been used according to the current road network problem and its condition. In this paper, study the actual cause behind the congestion through a primary survey and observe the situation of the road at peak hours (9.30 am-10.30 am). Based on the analysis of the current situation, the paper presents some logical solutions that are available within the Midnapore transport system and only need proper execution in the right way. The advantage of the paper is the recommended solutions are supportable by financial conditions, less harassment to common people, safety from accidents, reduced trip delay, and welfare for the city environment. This paper also proves that Remote Sensing and GIS an important tools for analysis and planning.

Appendix:

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References

[1] S. Krishnamurthy and K. M. Kockelman, "Propagation of Uncertainty in Transportation Land Use Models: Investigation of DRAM-EMPAL and UTPP Predictions in Austin, Texas," Transportation Research Record: Journal of the Transportation Research Board, vol. 1831, no. 1, pp. 219–229, 2003, doi: 10.3141/1831-25.
[2] F. Ahmadzai, "Analyses and modeling of urban land use and road network interactions using spatial-based disaggregate accessibility to land use," Journal of Urban Management, vol. 9, no. 3, pp. 298–315, 2020.
[3] X. Mao, X. Xu, S. Tang, and X. Li, "Providing and finding k-road-coverage efficiently in wireless sensor networks," Wireless Communications and Mobile Computing, vol. 12, no. 12, pp. 1053–1065, 2012.
[4] A. E. Ohazulike, G. Still, W. Kern, and E. C. van Berkum, "An origin–destination based road pricing model for static and multi-period traffic assignment problems," Transportation Research Part E: Logistics and Transportation Review, vol. 58, pp. 1–27, 2013.
[5] C. Zhang, X. Yan, L. Ma, and M. An, "Crash Prediction and Risk Evaluation Based on Traffic Analysis Zones," Mathematical Problems in Engineering, vol. 2014, pp. 1–9, 2014, doi: 10.1155/2014/987978.
[6] P. Arulbalaji, "Analysis of land use/land cover changes using geospatial techniques in Salem district, Tamil Nadu, South India," SN Applied Sciences, vol. 1, no. 5, May 2019, doi: 10.1007/s42452-019-0485-5.
[7] X. Yao et al., "How can urban parks be planned to mitigate urban heat island effect in 'Furnace cities'? An accumulation perspective," Journal of Cleaner Production, 2022, doi: 10.1016/j.jclepro.2021.129852.
[8] Y. Sun, M. Hrušovský, C. Zhang, and M. Lang, "A time-dependent fuzzy programming approach for the green multimodal routing problem with rail service capacity uncertainty and road traffic congestion," Complexity, vol. 2018, 2018.
[9] C. Wang, M. A. Quddus, and S. G. Ison, "Impact of traffic congestion on road accidents: A spatial analysis of the M25 motorway in England," Accident Analysis amp; Prevention, vol. 41, no. 4, pp. 798–808, 2009, doi: 10.1016/j.aap.2009.04.002.
[10] A. J. Ayodeji, E. D. Sunday, N. C. Friday, and S. S. Ayo, "Causes of Traffic Congestion and Possible Solutions along Akesan-Igando Road, Lagos Nigeria," The International Journal of Humanities amp; Social Studies, vol. 9, no. 11, 2021, doi: 10.24940/theijhss/2021/v9/i11/hs2111-030.
[11] G. Weisbrod and S. Fitzroy, "Traffic Congestion Effects on Supply Chains: Accounting for Behavioral Elements in Planning and Economic Impact Models," Supply Chain Management - New Perspectives. InTech, 2011. doi: 10.5772/23057.
[12] A. Mohan Rao and K. Ramachandra Rao, "MEASURING URBAN TRAFFIC CONGESTION – A REVIEW," International Journal for Traffic and Transport Engineering, vol. 2, no. 4, pp. 286–305, 2012, doi: 10.7708/ijtte.2012.2(4).01.
[13] S. Ye, "Research on Urban Road Traffic Congestion Charging Based on Sustainable Development," Physics Procedia, vol. 24, pp. 1567–1572, 2012, doi: 10.1016/j.phpro.2012.02.231.
[14] H. Uniyal and D. H. Gandhi, "Traffic Congestion - Causes and Solution: A Study of Kota City," International Journal of Trend in Scientific Research and Development, vol. Volume-2, no. Issue-2, pp. 250–253, 2018, doi: 10.31142/ijtsrd8332.
[15] H. Yu, P. Liu, H. Wang, and Q. Liang, "Kernel Density Estimation Based Method for Hazardous Road Segments Identification," CICTP 2012. American Society of Civil Engineers,

2012. doi: 10.1061/9780784412442.213.
[16] M. Beuran, M. Gachassin, and G. Raballand, "Are There Myths on Road Impact and Transport in Sub-Saharan Africa?," Development Policy Review, vol. 33, no. 5, pp. 673–700, 2015, doi: 10.1111/dpr.12125.
[17] R. Subba, "Addressal to the Rising Problem of Traffic Congestion in Kalimpong, West Bengal: Causes and Preventive Measures," Advanced Journal of Social Science, vol. 7, no. 1, pp. 60–70, 2020, doi: 10.21467/ajss.7.1.60-70.
[18] W. A. Bagwan and R. S. S Gavali, "Dam-triggered Land Use Land Cover change detection and comparison (transition matrix method) of Urmodi River Watershed of Maharashtra, India: a Remote Sensing and GIS approach," Geology, Ecology, and Landscapes, 2021, doi: 10.1080/24749508.2021.1952762.
[19] L. He et al., "On-road emission measurements of reactive nitrogen compounds from heavy-duty diesel trucks in China," Environmental Pollution, vol. 262, p. 114280, 2020, doi: 10.1016/j.envpol.2020.114280.
[20] T. Guo, S. Song, and W. Ma, "Point and Interval Forecasting of Groundwater Depth Using Nonlinear Models," Water Resources Research, 2021, doi: 10.1029/2021WR030209.
[21] T. K. Anderson, "Kernel density estimation and K-means clustering to profile road accident hotspots," Accident Analysis amp; Prevention, vol. 41, no. 3, pp. 359–364, 2009, doi: 10.1016/j.aap.2008.12.014.
[22] H. A. S. Sandhu, G. Singh, M. S. Sisodia, and R. Chauhan, "Identification of Black Spots on Highway with Kernel Density Estimation Method," Journal of the Indian Society of Remote Sensing, vol. 44, no. 3, pp. 457–464, 2016, doi: 10.1007/s12524-015-0500-2.
[23] L. Tang, Z. Kan, X. Zhang, F. Sun, X. Yang, and Q. Li, "A network Kernel Density Estimation for linear features in space–time analysis of big trace data," International Journal of Geographical Information Science, vol. 30, no. 9, pp. 1717–1737, 2015, doi: 10.1080/13658816.2015.1119279.
[24] B. Romano and Z. Jiang, "Visualizing Traffic Accident Hotspots Based on Spatial-Temporal Network Kernel Density Estimation," Proceedings of the 25th ACM SIGSPATIAL International Conference on Advances in Geographic Information Systems. ACM, 2017. doi: 10.1145/3139958.3139981.
[25] M. T. Rahman, A. Jamal, and H. M. Al-Ahmadi, "Examining hotspots of traffic collisions and their spatial relationships with land use: A GIS-based geographically weighted regression approach for Dammam, Saudi Arabia," ISPRS International Journal of Geo-Information, vol. 9, no. 9, p. 540, 2020.
[26] A. S. Mohaymany, M. Shahri, and B. Mirbagheri, "GIS-based method for detecting high-crash-risk road segments using network kernel density estimation," Geo-spatial Information Science, vol. 16, no. 2, pp. 113–119, 2013, doi: 10.1080/10095020.2013.766396.
[27] M. G. Sreelekha, K. Krishnamurthy, and M. V. L. R. Anjaneyulu, "Interaction between Road Network Connectivity and Spatial Pattern," Procedia Technology, vol. 24, pp. 131–139, 2016, doi: 10.1016/j.protcy.2016.05.019.
[28] A. Quium and S. Hoque, "The completeness and vulnerability of road network in Bangladesh," Engineering concerns of flood, vol. 1, pp. 59–75, 2002.
[29] C. B. Daniel, S. Saravanan, and S. Mathew, "Gis based road connectivity evaluation using graph theory," in Transportation Research: Proceedings of CTRG 2017, 2020, pp. 213–226.
[30] M. G. Sreelekha, K. Krishnamurthy, and M. Anjaneyulu, "Assessment of topological pattern of urban road transport system of Calicut city," Transportation Research Procedia, vol. 17, pp. 253–262, 2016.
[31] H. J. Eoh, M. K. Chung, and S.-H. Kim, "Electroencephalographic study of drowsiness in simulated driving with sleep deprivation," International Journal of Industrial Ergonomics, vol. 35, no. 4, pp. 307–320, 2005.

[32] M. Fink, K. Ivanová, D. Bernardová, T. Arkhangelska, and K. Kašparová, "Social Responsibility ETA Index 2019.," International Journal of Curriculum and Instruction, vol. 12, pp. 50–65, 2020.
[33] K. J. Kansky, Structure of transportation networks: relationships between network geometry and regional characteristics. The University of Chicago, 1963.
[34] D. Watanabe, "A study on analyzing the grid road network patterns using relative neighborhood graph," in The Ninth International Symposium on Operations Research and Its Applications, 2010, pp. 112–119.
[35] V. Pascucci and R. J. Frank, "Global static indexing for real-time exploration of very large regular grids," in Proceedings of the 2001 ACM/IEEE Conference on Supercomputing, 2001, p. 2.