Geoinformatics driven Smart Urban Road Network Planning with Renewable Energy Road Elements and Accident Hotspot Analysis

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***Abstract*—Traffic congestion along urban corridors is a growing concern in rapidly developing cities due to increasing vehicle population and limited road capacity. This study focuses on analyzing congestion patterns using field-based datasets, including traffic volume counts, speed measurements, delay studies, and road inventory surveys. The collected data helps in evaluating key traffic parameters such as volume, speed, and density, particularly during peak hours when congestion is most severe. The analysis reveals that intersections, commercial areas, and stretches with mixed traffic conditions experience the highest levels of congestion. Major contributing factors include inadequate infrastructure, poor traffic management, on-street parking, and a high proportion of private vehicles. The study highlights the impact of congestion in terms of increased travel time, fuel consumption, and environmental pollution. Based on the findings, both short-term and long-term measures such as signal optimization, parking control, infrastructure improvement, and promotion of public transport are recommended to enhance traffic flow and reduce congestion along urban corridors.**

***Index Terms*—Traffic congestion, field-based data, traffic volume, traffic density, peak hours, road capacity, traffic management, on-street parking, vehicle growth, pollution, congestion mitigation.**

I. INTRODUCTION

Transportation is the means of carrying goods and people from one place to another and plays a vital role in economic and social development. It facilitates the physical movement of individuals as well as commodities through various modes such as road, rail, water, and air transport. Among these, road transport is the most widely used and cost-effective mode in India due to its flexibility and accessibility. At present, India has one of the largest road networks in the world, extending to over 6.6 million kilometers (as of 2026), comprising Expressways, National Highways, State Highways, Major District Roads, Other District Roads, and Village Roads. Roads serve as the backbone of transportation in the country, handling the majority of passenger and freight movement. However, the road transport system faces several challenges, including increasing traffic congestion, inadequate road maintenance, parking issues, vehicular pollution, and concerns related to road safety, especially with the rapid growth in vehicle population and urbanization.

A. Description of Satara City

Satara city is administered by the Municipal Corporation and falls under the Satara Municipal Region in Maharashtra, India. Due to continuous urban growth and development, the population has increased steadily over the years. Based on projected growth rates, the estimated population of Satara city in 2026 is approximately 1,55,000, with males around 78,500 and females around 76,500. The metropolitan population is estimated to be about 1,95,000, with nearly 99,000 males and 96,000 females. This rise in population has significantly increased the demand for transportation, infrastructure, and urban services, thereby contributing to traffic congestion and the need for improved road network planning.

B. Transport in Satara City

Satara city is well connected to the rest of Maharashtra through an efficient network of road and rail transport. The city lies along the important National Highway 48, which connects major cities like Mumbai and Chennai and forms part of the Golden Quadrilateral.

This highway has been upgraded to a multi-lane divided carriageway, with the Pune–Satara stretch expanded to six lanes to handle increasing traffic demand. A bypass road has also been developed to divert through traffic and reduce congestion within the city. Additionally, State Highway connections link Satara to nearby regions such as Mahabaleshwar and Solapur, improving regional accessibility. To reduce congestion within the city, a bypass road has been developed to divert heavy and through traffic away from the main urban areas. This highway has been upgraded to a multi-lane divided carriageway, with the Pune–Satara stretch widened to six lanes to handle increasing traffic volume. In addition, state highways connect Satara to nearby towns such as Mahabaleshwar and Solapur, improving regional accessibility.

Within the city, an extensive network of roads connects important locations such as schools, colleges, the ST stand, markets, banks, and government offices. These roads also link surrounding rural areas to the city for employment, education, and daily activities. The internal road system further connects with major highways, ensuring smooth movement of people and goods. However, with the rapid growth in vehicle numbers, the city is facing increasing challenges related to traffic congestion and road maintenance.

This Paper concentrated on Satara City's traffic jams and road upkeep.

C. Congestion of Traffic

Queuing, slower speeds, and longer travel times are all consequences of traffic congestion that have a negative economic impact on urban areas and their residents [1]. The analysis of traffic congestion in Satara City is covered in the first section of this paper. Estimating the volume of traffic on the road at congested points in Satara City is the first step toward minimizing traffic congestion. A popular technique for estimating traffic congestion is to use a traffic volume survey and count the number of cars traveling through congested areas during peak traffic. The city's insufficient number of traffic signals and poor control system are the primary causes of traffic congestion. Only one of Satara City's many crowded locations has a traffic signal. Satara City's increasing traffic congestion necessitates effective traffic management for the city's healthy mobility.[2]

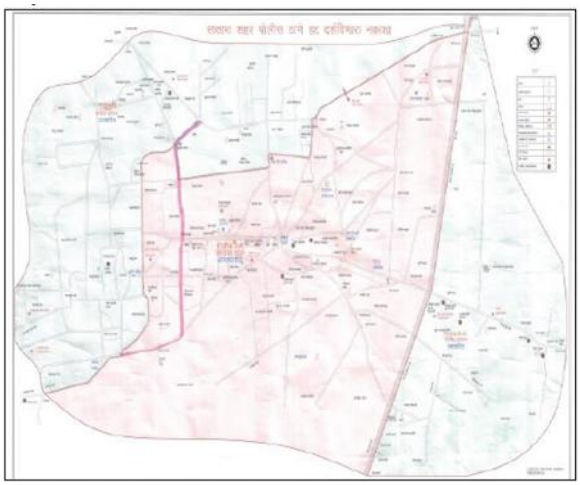

Fig. 1: Road Map of Satara City

1) Objective:

To analyse traffic congestion patterns along the selected urban corridor using field-based datasets.

II. METHODOLOGY

The methodologies adopted in the selected studies involve a combination of field data collection, geospatial analysis, and performance evaluation techniques to assess urban traffic congestion [3], a field-based methodology was used in which traffic volume data were collected along urban corridors at different time intervals and analyzed to determine peak hour congestion patterns [4], a GIS-based approach was adopted by integrating real-time traffic data with spatial analysis tools to identify traffic flow variations and major congestion zones [5], field surveys were conducted to collect traffic volume and delay data at intersections, followed by the application of Level of Service (LOS) analysis to evaluate intersection performance. [6], a mixed-method approach was used, combining field observations, secondary data analysis, and statistical techniques to investigate the causes and impacts of traffic congestion, focusing on factors such as rapid vehicle growth, inadequate infrastructure, and poor traffic management.

A. Gathering Information

Information is gathered from Nagarpalika, the PWD office, and the traffic control office about Satara City's road plan, traffic congestion, and the state of the city's roads and drainage system.

B. Traffic Congestion Field Survey

A typical technique used to assess the quantity of traffic on the road at congested spots in Satara City is the traffic volume survey, which counts the number of cars traveling through congested areas during peak traffic.[2]

The traffic density-based analysis is conducted at several locations and times, such as during morning and evening rush hour. The locations chosen for the traffic congestion analysis are significantly closer to the public school, local market, and government buildings. The locations that have been decided upon for analysis are:

1) The Satara ST stand
2) Naka Powai
3) The Gol bag circle at Rajwada Chowk

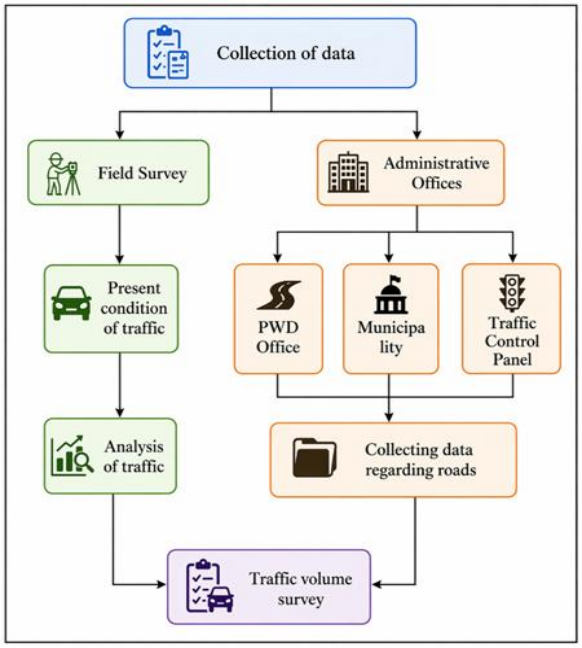

Fig. 2: Collected Data

III. RESULT & DISCUSSION

Traffic studies are conducted to understand and evaluate traffic characteristics, which play an important role in geometric road design and traffic control for ensuring safe and efficient movement of vehicles. In this study, a traffic volume survey was carried out to examine the traffic flow within Satara city and to identify congestion at critical locations. Traffic volume refers to the number of vehicles passing through a specific cross-section of a road over a given period of time, and it is commonly expressed in vehicles per minute, per hour, or per day. The collected traffic data were broadly categorized into different vehicle types such as two-wheelers (bikes), auto-rickshaws, cars/taxis, and buses/trucks. The summarized results of the data are presented in the following tables.

A. The Satara ST Stand

The ST stop is situated on a major road that leads to Satara City and National Highway Number 48. There are a lot of route walkers and huge cars.

Table 1 gives the details of survey of peak hours 09:00am to 10:00am & Table 2 gives of survey of peak hours 6 pm to 7 pm

Vehicles	Satara stands to Powai naka	Powai naka to Satara stand	Satara stands to civil hospital road	Total
Bikes	1543	1194	201	2938
Auto -rickshaw	156	135	101	392
Car / Taxis	213	124	45	382
Buses / Trucks	34	22	04	60
Total (veh/hr)				3772

Table 1: Survey conducted between 9:00 and 10:00 a.m.

20% more volume is taken into account for future development in order to compute density.

Density = rate of flow / time = 3772 + (3772 x 0.2) / 1 = 4526 veh/hr

Table 2: Survey conducted between 6:00 and 7:00 p.m.

Vehicles	Satara stands to Powai naka	Powai naka to Satara stand	Satara stands to civil hospital road	Total
Bikes	1226	1256	216	2698
Auto -rickshaw	219	175	98	492
Car / Taxis	121	264	54	439
Buses / Trucks	46	32	03	81
Total (veh/hr)				3710

20% more volume is taken into account for future development in order to compute density.
Density = rate of flow/time = 3710 + (3710 x 0.2) / 1 = 4452 veh/hr

B. Powai Naka

Powai Naka in Satara is a major traffic junction where several important city roads intersect, making it one of the busiest areas in the city. Due to its proximity to the market area, bus routes, and its connection to National Highway 48, it experiences heavy traffic flow throughout the day. A large number of two-wheelers, cars, auto-rickshaws, and buses, along with significant pedestrian movement, contribute to frequent congestion, especially during peak hours.
Bombay Rest = A-B. Road to Powai Naka, C-D = Y. C. CLG Road to Powai Naka, E-F = Rajwada Road to Powai Naka, G-H = Police Head Quarter Road to Powai Naka, I-J = Satara Stand Road to Powai Naka, K-L = Civil Hospital Road to Powai Naka

Table 3 provides information on the Powai Naka (Towards) peak hours survey from 9:00 am to 10:00 am, while

Vehicles	A-B	C-D	E-F	G-H	I -J	K-L	Total
Bikes	966	874	798	1012	986	856	5492
Auto / rickshaw	94	65	53	78	45	60	395
Car / Taxis	203	179	123	106	120	93	824
Buses / Trucks	16	23	11	15	7	5	77
Total (veh/hr)							6788

Table 3: Survey at peak hour 09:00am to 10:00am Powai naka (Towards)
To calculate density 20% additional volume is consider for future development.
To find density time is taken 1 hour,
Density = rate of flow / time
= 6788 + (6788 x 0.2) / 1
= 8146 veh/hr

Table 4 provides information on the peak hours survey from 9:00 pm to 10:00 pm. Away, or powai naka

Vehicles	B-A	D-C	F-E	J-I	L-K	Total
Bikes	968	958	843	826	870	4465
Auto / rickshaw	97	91	27	34	23	272
Car / Taxis	287	156	155	120	131	849
Buses / Trucks	8	29	19	11	7	74
Total (veh/hr)						5660

Table 4: Survey at peak hour 09:00pm to 10:00pm Powai naka (Away) To calculate density 20% additional volume is consider for future development. To find density time is taken 1 hour Density = rate of flow / time = 5660+ (5660 x 0.2) / 1 = 6792 veh/hr Total Density= 8146+6792 = 14938 veh/hr

Table 5 gives the details of survey of peak hours 06:00am to 07:00am Powai naka (Towards) & Table 6 gives of survey of peak hours 06:00am to 07:00am Powai naka (Away)

Vehicles	A-B	C-D	E-F	G-H	I -J	K-L	Total
Bikes	978	988	531	910	817	619	4843
Auto / rickshaw	91	82	60	117	61	66	477

Car / Taxis	72	113	63	54	76	44	422
Buses / Trucks	13	18	31	8	9	04	83
Total (veh/hr)							5825

Table 5: Powai naka (Towards) survey conducted at peak hours of 06:00 am to 07:00 am
20% more volume is taken into account for future development in order to compute density.
It takes an hour to determine density.
Density is calculated as follows: 5825 + (5825 x 0.2) / 1 = 6990 veh/hr.

Table 6: Powai naka (Away) survey conducted between peak hours of 06:00 am to 07:00 am

Vehicles	B-A	D-C	F-E	J-I	L-K	Total
Bikes	803	913	558	618	556	3448
Auto / rickshaw	96	85	75	130	83	469
Car / Taxis	279	269	114	224	129	1015
Buses / Trucks	13	30	29	15	16	103
Total (veh/hr)						5035

20% more volume is taken into account for future development in order to compute density.
It takes an hour to determine density.
Density is equal to flow rate divided by time.
= 5035+ (5035 x 0.2) / 1
= 6042 veh/hr
Total Density= 6990+6042 =13032 veh/hr

C. Rajwada (circle of a Gol bag)
There is a food court, a children's play park, and a local city bus terminus in this neighborhood. Many people congregate here in the evenings and on holidays, which increases the flow of automobiles and motorcyclists.
A-B is the Powai Naka Road to Rajwada; C-D is the Samarth Mandir to Rajwada Circle; and E-F is the Moti Tale Road.

Table 7 provides survey information for Rajwada (Gol bag circle) during peak hours of 09:00 to 10:00 a.m. &

Vehicle	A-B	C-D	E-F	B-A	D-C	F- E	Total
	Towards	Towards	Towards	Away	Away	Away	Towards + Away
Bikes	409	642	32	387	606	60	2136
Auto / rickshaw	66	82	72	78	53	54	405
Car / Taxis	115	97	13	90	47	22	384
Buses/Trucks	22	11	18	15	17	18	101
Total (veh/hr)							3026

Table 7: Survey conducted between 9:00 and 10:00 a.m.
20% more volume is taken into account for future development in order to compute density.
It takes an hour to determine density.
Density is calculated as follows:
3026 + (3026 x 0.2) / 1 = 3631 veh/hr.

Table 8 provides survey results during peak hours of 5:00 to 6:00 p.m.

Vehicle	A-B	C-D	E-F	B-A	D-C	F- E	Total
	Towards	Towards	Towards	Away	Away	Away	Towards + Away
Bikes	697	645	66	308	538	67	2321
Auto / rickshaw	164	93	35	55	64	36	44
Car / Taxis	118	132	08	102	71	19	450
Buses / Trucks	18	06	11	08	07	10	60
Total (veh/hr)							2875

Table 8: Survey conducted between 5:00 and 6:00 p.m. 20% more volume is taken into account for future development in order to compute density.
It takes an hour to determine density.
Density = flow rate/time = 2875 + (2875 x 0.2) = 3450 veh/hr
Total Density= 3631+3450 =7081 veh/hr

Fig. 1: Area of Satara City Traffic Hotspot

IV. CONCLUSION

In order to investigate traffic congestion in Satara during both peak and off-peak hours, the current study was conducted. Data were gathered for this purpose by locating and surveying many sites at various times of day, both during the day and at night. According to the investigation, high market collaboration with the local traffic control agency. The investigation showed that excessive market density and insufficient road width are two major causes of traffic congestion. Along with the tactics used to control and manage traffic flow during peak hours, many traffic management models were also examined in collaboration with the local traffic control agency.

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