Analysis of traffic delay and pollution for Bapatla region: A Case study

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Abstract-Recent studies indicate that a country's transportation system must prioritize road conditions to achieve efficient traffic management and reduce congestion. Developed nations, including India, are wrestling with challenges such as rising vehicle operating costs, pollution, and safety concerns. To identify efficient traffic operations, several parameters can be considered, including vehicle types, speed limits, traffic mix, and adherence to regulations. This paper addresses key issues related to the Indian road scenario, specifically focusing on vehicle speed, delays, and pollutants emitted by vehicles.

I INTRODUCTION

Traffic congestion is a persistent challenge faced by urban and suburban areas worldwide. As cities expand and motor vehicle ownership rises, the strain on existing transportation infrastructure intensifies, resulting in slower commute times, increased fuel consumption, and heightened stress levels for commuters. This issue extends beyond mere inconvenience; it significantly impacts economic productivity, public health, and environmental sustainability.

The primary causes of traffic congestion include insufficient infrastructure, poor integration of public transportation, and ineffective traffic management. The environmental consequences of congestion are notable, as prolonged idling and stop-and-go traffic lead to higher emissions and deteriorating air quality. For instance, Delhi is currently experiencing severe congestion issues, prompting the closure of schools and businesses to mitigate major health hazards.

In addition to pollution, there are economic repercussions, such as lost time, increased fuel costs, and delayed deliveries, which affect both individuals and businesses. Socially, congestion can lead to increased stress; crowded roads heighten frustration, reduce family time, and contribute to incidents of road rage.

While banning older vehicles that tend to produce higher emissions may alleviate the problem to some extent, it is widely believed that a proper integration of public transportation could significantly reduce pollution levels, potentially by tenfold.

II LITERATURE

A review of existing scientific literature on the following subjects is presented in this chapter: Developments in the Monitoring and Management of Road Traffic Congestion

- Development of Methods for Evaluating Traffic Efficiency
- Modelling Air Quality in Complicated Urban Areas
- Creation of Point Sampling Technology for Monitoring Urban Pollution
- Vehicle Communication Using Vehicle Delay-Tolerant Networks (VDTNs)
- Effects of Policy Changes and Sustainable Mobility on Urban Air Quality
- Willingness of the Public to Pay for Safety and Health Measures in Public Transportation
- Intelligent Traffic Management to Improve Urban Air Quality
- Modelling and Mechanisms of the Dispersion of Vehicle Pollutants in Urban Settings
- Urban Speed Limit Policies Effects on Public Attitudes and Behaviour
- Techniques for Estimating the Urban Traffic State
- Methods for Bottleneck Management and Congestion Pricing
- Driver Behaviour and Advanced Traveller Information Systems (ATIS)
- Dynamic Shared-Lane Techniques for Optimizing Bottleneck Capacity

- Using Sparse GPS Data to Model Urban Travel Times Probabilistically
- Systems for Distributed Traffic Management in Urban Networks
- Methods for Estimating Greenhouse Gas (GHG) Emissions in Road Transportation

III METHODOLOGY

Review of Literature

To investigate earlier research on traffic analysis, delay patterns, and pollutant estimation, a thorough literature survey was carried out. This aided in defining the current study's scope and identifying existing approaches.

Selection of the Study Area

A number of criteria, including vehicle activity, environmental concerns, and the importance of urban development, were taken into consideration while choosing the research region. This guaranteed that the information acquired would be relevant to the study's goals.

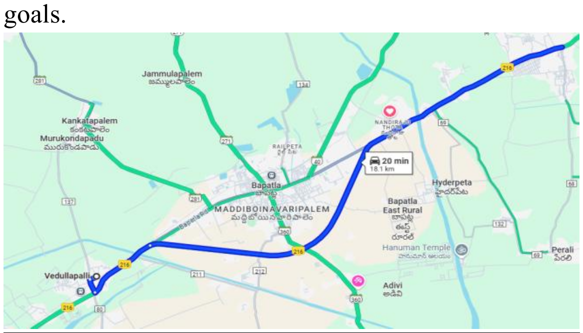

Fig 1. Study area in Bapatla

Data Collection

In order to assess pollutant indicators and traffic performance, primary and secondary data were methodically gathered. This comprises:

<u>Traffic Data:</u> Gathered by manual counting and video monitoring to evaluate the flow and movement of vehicles. Using travel time measurements, delay analysis is done to find bottlenecks and congestion during peak hours.

<u>Pollution Data:</u> Obtained by monitoring the quality of the air in order to measure emissions related to traffic patterns. National pollution

Interpretation of Data

Quantitative and visual methods were used to process and interpret the gathered data. Important steps included:

<u>Vehicle Classification:</u> In order to comprehend the traffic mix and its effects, vehicles were grouped according to their size and kind.

Table 1. Traffic Data for 2 wheeler vehicles

ONE HOUR TRAFFIC DATA					
Sno	Two Wheel Vehicles towards Bapatla(0.25X)	1.0X	Length(m)	SPEED in m/s	SPEED in KM /HR
1	2.86	0.715	6.04	8.448	30.41
2	3.58	0.895	6.04	6.749	24.29
3	3.31	0.8275	6.04	7.299	26.28
4	3.33	0.8325	6.04	7.255	26.12
5	3.31	0.8275	6.04	7.299	26.28
6	3.5	0.875	6.04	6.903	24.85
7	3.28	0.82	6.04	7.366	26.52
8	3.16	0.79	6.04	7.646	27.52
9	3.11	0.7775	6.04	7.768	27.97
10	3.12	0.78	6.04	7.744	27.88

<u>Speed and Delay Analysis:</u> To identify inefficiencies in road usage, speed profiles and delay indices were computed.

<u>Pollution Estimation:</u> Traffic volumes and pollutant concentration levels were correlated in order to estimate emission levels.

Table 2. Primary Air Pollutants

Sulphur Oxides (SO_x)	Carbon Monoxide (CO)
Nitrogen Oxides (NO_x)	Carbon Dioxide (CO_2)
Volatile Organic Compounds (VOC)	Hydrocarbons (HC)
Ammonia (NH_3)	Particulate Matter (PM)
Radioactive pollutants	Chlorofluorocarbons (CFC)
Toxic Metals like Lead, Cadmium and Copper	

Table 3. Secondary Air Pollutants

Photochemical smog
Peroxyacetyl Nitrate (*PAN*)
Ozone (O_3)

Interpretation of the Results and Development of Conclusions

Meaningful insights were extracted from the analysis results through interpretation. These observations served as the foundation for closing thoughts and suggestions meant to enhance traffic flow and reduce pollution in the research region.

DATA ANALYSIS

Vehicle Classification:

Accurate vehicle classification is essential to urban traffic management in order to handle pollution, congestion, and infrastructure planning. Using video analytics and manual verification, the vehicles in this study were categorized as two-wheelers, three-wheelers, four-wheelers, six-wheelers (heavy vehicles), and high-occupancy vehicles (buses). Real-time identification and classification based on size and form characteristics were made possible by automated video processing, guaranteeing accurate data for additional research.

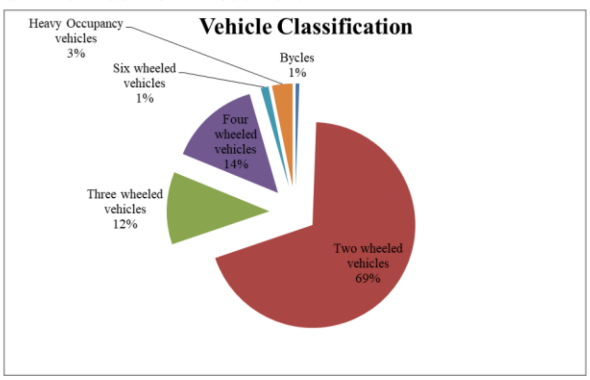

Fig 2 : Classification of vehicles in study area

Two Wheelers: In Indian cities, two-wheelers make up a sizable amount of traffic. To enhance safety and policy initiatives, exact identification was achieved through the use of video-based classification.

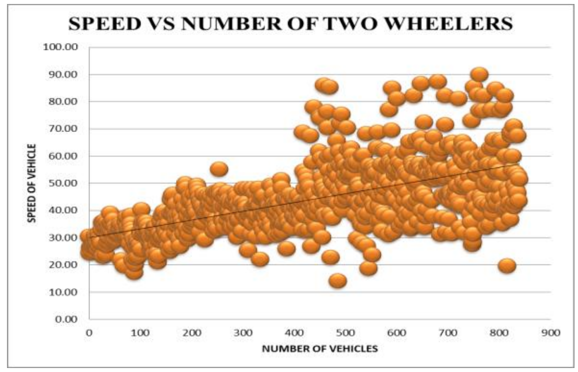

Fig 3. Vehicular speed classification of two wheelers

Three Wheelers: In order to address their distinct function in semi-urban transportation, computer vision techniques were used to identify three-wheelers, which are crucial for regional mobility.

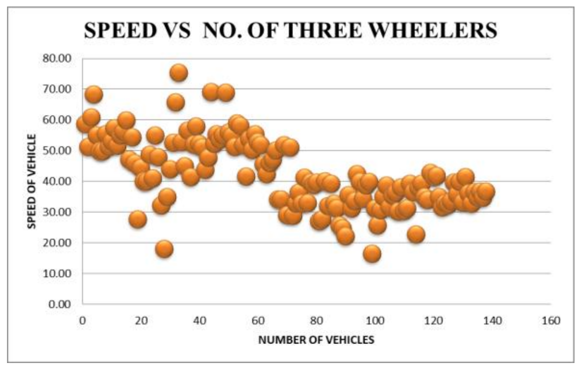

Figure 4. Vehicular speed classification of three wheelers

Four-wheelers: Using trend analysis and image processing, the increase in automobiles, SUVs, and vans was examined for its effects on emissions and traffic.

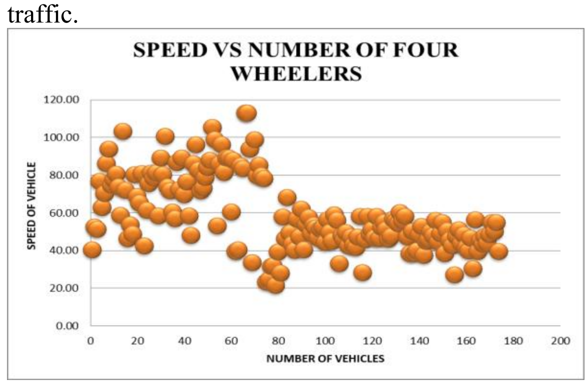

Figure 5. Vehicular speed classification of four wheelers

Six-wheelers and buses: In order to evaluate their influence on the environment and their contribution to freight and public transportation, heavy and high-occupancy vehicles were categorized.

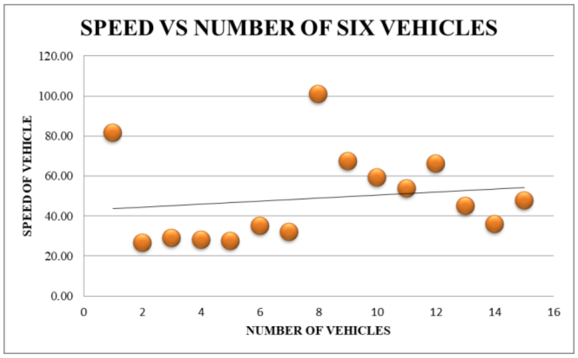

Fig 6. Vehicular speed classification of six wheelers

Economic Impact and Traffic Delays:

Economic productivity is directly impacted by traffic delays. Logistics expenses make around 13–15% of India's GDP, which is more than the global average. Higher vehicle speeds and better road infrastructure can lower these expenses, boost competitiveness, and aid in GDP growth. While shorter commutes enhance people's access to services and quality of life, faster commodities movement lowers inventory and storage expenses for businesses. Government income, job creation, and economic output are all multiplied by highway investments and delays.

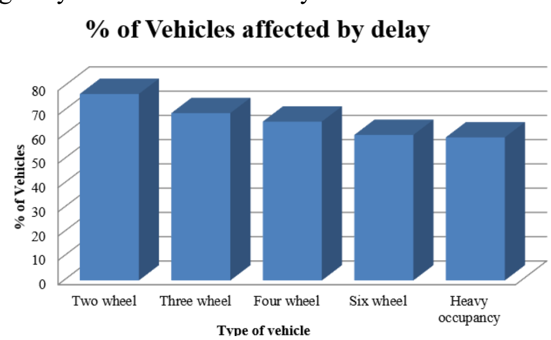

Figure 7: Percentage of Vehicles affected by delay

Vehicle Emissions and Pollution Estimation:

Many greenhouse gases (GHGs), including CO_2, CH_4, and N_2O, are produced by the transportation sector. Based on the kind of vehicle, engine capacity, and fuel type, standard emission factors (g/km) were used to estimate emissions. Each vehicle class's total emissions were calculated by combining pollutant-specific emission factors with information on engine size and usage.

Table 4: Two wheeler pollution data

S.No	Two wheelers Name of Vehicle	CC	Fuel Emission Factor(Kg CO2/Lit)	Fuel efficien cy of vehicle(	Emission Factor(Kg/CO2/Km)	Emission Factor(Kg/CO2/Km) with uplift factor
780	Royal Enfield	350	2.27193	30	0.075731	0.0833041
781	Royal Enfield	350	2.27193	30	0.075731	0.0833041
782	Royal Enfield	350	2.27193	30	0.075731	0.0833041
783	Royal Enfield	350	2.27193	30	0.075731	0.0833041
784	TVS Victor	110	2.27193	72	0.031554583	0.034710042
785	Bajaj Chetak	100	2.27193	40	0.05679825	0.062478075
786	Bajaj Chetak	100	2.27193	40	0.05679825	0.062478075
787	Bajaj Chetak	100	2.27193	40	0.05679825	0.062478075
788	Honda SP	125	2.27193	65	0.034952769	0.038448046
789	Honda SP	125	2.27193	65	0.034952769	0.038448046
790	Honda SP	125	2.27193	65	0.034952769	0.038448046
791	Honda SP	125	2.27193	65	0.034952769	0.038448046
792	Honda SP	125	2.27193	65	0.034952769	0.038448046
793	Honda SP	125	2.27193	65	0.034952769	0.038448046
794	Vespa	125	2.27193	40	0.05679825	0.062478075
795	Vespa	125	2.27193	40	0.05679825	0.062478075
796	Vespa	125	2.27193	40	0.05679825	0.062478075
797	Vespa	125	2.27193	40	0.05679825	0.062478075
798	Vespa	125	2.27193	40	0.05679825	0.062478075
799	TVS NTORQ	125	2.27193	41	0.055412927	0.06095422
800	TVS NTORQ	125	2.27193	41	0.055412927	0.06095422
801	Hero Honda CBZ Xtre	150	2.27193	50	0.0454386	0.04998246

Table 5: Efficiency factor of four wheelers

S.No	Four wheelers Name of Vehicle	CC	Fuel Emission Factor(Kg CO2/Lit)	Fuel efficiency of vehicle(Km/Lit)	Emission Factor (Kg/CO2/Km)	Emission Factor(Kg/CO2/Km) with uplift factor
40	Honda City	1600	2.27193	18	0.126218333	0.138840167
41	Honda City	1600	2.27193	18	0.126218333	0.138840167
42	Toyota Innova Crysta	2500	2.27193	14	0.162280714	0.178508786
43	Toyota Innova Crysta	2500	2.27193	14	0.162280714	0.178508786
44	Toyota Innova Crysta	2500	2.27193	14	0.162280714	0.178508786
45	Toyota Innova Crysta	2500	2.27193	14	0.162280714	0.178508786
46	Toyota Innova Crysta	2500	2.27193	14	0.162280714	0.178508786
47	Toyota Innova Crysta	2500	2.27193	14	0.162280714	0.178508786
48	Toyota Innova Crysta	2500	2.27193	14	0.162280714	0.178508786
49	Toyota Innova Crysta	2500	2.27193	14	0.162280714	0.178508786
50	Maruthi Suzuki vitara brezza	2000	2.27193	17	0.133642941	0.147007235
51	Maruthi Suzuki vitara brezza	2000	2.27193	17	0.133642941	0.147007235
52	Maruthi Suzuki vitara brezza	2000	2.27193	17	0.133642941	0.147007235
53	Maruthi Suzuki vitara brezza	2000	2.27193	17	0.133642941	0.147007235
54	Maruthi suzuki alto	800	2.27193	22	0.103	0.1133
55	Maruthi suzuki alto	800	2.27193	22	0.103	0.1133
56	Maruthi suzuki alto	800	2.27193	22	0.103	0.1133
57	Maruthi suzuki alto k10	1000	2.27193	20	0.1135965	0.12495615
58	Maruthi suzuki alto k10	1000	2.27193	20	0.1135965	0.12495615
59	Maruthi suzuki alto k10	1000	2.27193	20	0.1135965	0.12495615
60	Maruthi suzuki alto K10	1000	2.27193	20	0.1135965	0.12495615
61	Maruthi suzuki alto K10	1000	2.27193	20	0.1135965	0.12495615
62	Kia Carens	1600	2.6444	14	0.188885714	0.207774286
63	Kia Carens	1600	2.6444	14	0.188885714	0.207774286
64	Kia Carens	1600	2.6444	14	0.188885714	0.207774286
65	Kia Carens	1600	2.6444	14	0.188885714	0.207774286
66	Mahindra bolero neo	2000	2.6444	17	0.155552941	0.171108235
67	Hyundai venue	2000	2.27193	18	0.126218333	0.138840167

Emission Factors: Based on national norms, these are broken down by vehicle type (two-wheelers, four-wheelers, etc.), fuel, and engine capacity.

CO_2, NOx, SOx, PM, and secondary pollutants including ozone were among the pollutants that were monitored.

Method of Calculation:

Total emissions = Emission factor x mileage × number of cars

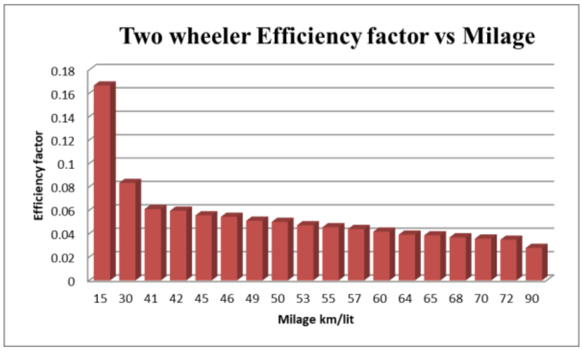

Fig 8. Efficiency factor of two wheelers

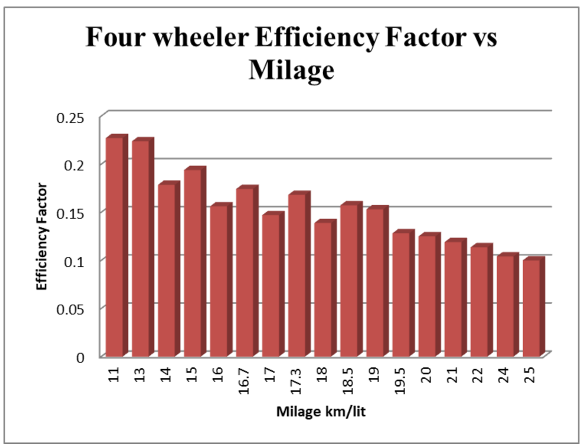

Fig 9. Efficiency factor of four wheelers

This study combines pollution estimation, delay evaluation, and vehicle categorization to give a thorough grasp of traffic dynamics and their effects on the environment and the economy. In Bapatla and other comparable urban contexts, the results validate evidence-based suggestions for sustainable transportation options, policy development, and urban design.

VII. CONCLUSION

The vehicle classification data indicates that two-wheelers constitute the majority at 69%, followed by four-wheelers at 14%, three-wheelers at 12%, and heavy occupancy vehicles at 3%, while both six-wheelers and bicycles each account for 1% of the total vehicle count.

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The main causes of inefficient fuel combustion are vehicles that are stalled in traffic or stop frequently, which causes them to idle longer and accelerate/decelerate more frequently.Increased emissions, particularly of CO_2, CO, NO_x, and particulate matter (PM), are the direct result of this.

The study corridor's two-wheeler vehicle pollution assessment showed a notable emission intensity of about 39 kg CO_2 per kilometer. This figure illustrates the environmental impact of two-wheeler transportation by reflecting the total CO2 contribution of all two-wheeler traffic over a one kilometer distance.

According to the emission analysis for four-wheeler cars, the research corridor's carbon dioxide output is roughly 19 kg CO_2 per kilometer. This figure is the total amount of CO2 emissions produced by all four-wheelers over a one-kilometer distance.

According to a comparative study of vehicle emissions, cars that run on diesel produce more pollutants than those that run on gasoline. Even though diesel engines are frequently more fuel-efficient, this difference is particularly noticeable in the discharge of nitrogen oxides (NO_x) and particulate matter (PM). In addition to being a major factor in the decline of local air quality, diesel vehicles' high emission rates also provide major health risks. In order to reduce the environmental impact of diesel-based transportation in the Bapatla region and along the NH 216 corridor, these findings highlight the necessity of stronger emission standards, quicker adoption of cleaner fuels and technologies, and policy-level measures.

Short-Term Mitigation Strategies:

Implement more stringent pollution regulations and routine vehicular checks. Encourage walking, bicycling, and public transportation. Put congestion pricing into effect and limit the number of high-emission vehicles that can enter sensitive areas.

Long-Term/Medium-Term:

Promote the use of CNG and electric vehicles more. Improve traffic control and road infrastructure. For focused interventions, create high-resolution emission inventories. Anticipated Results: These actions can improve public health, increase traffic safety, and cut urban air pollution by 30 to 50%.

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