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Study of Intelligent Traffic Management System for North India

Sharwan Nagar[1], Dinesh Kumar Samal[2], Siddharth Jain[3], Prashant Kumar[3]

[1]Postrgraduate Scholar, Department of Civil Engineering, School of Engineering & Technology, IIMT University, Meerut
[2]Supervisor, Assistant Professor, Department of Civil Engineering, School of Engineering & Technology, IIMT University, Meerut
[3]Assistant Professor, Department of Civil Engineering, School of Engineering & Technology, IIMT University, Meerut

Abstract
In recent years, the urbanization in North Indian cities has been accelerated at such a rate and existing road infrastructure has been suffocated to such an extent, the traffic congestion has been made too thick, the travel time is too long, the vehicular emissions and the amount of fuel consumption are too high. The traditional traffic control mechanisms are now obsolete in cities like Delhi, Chandigarh, Lucknow, Jaipur which have experienced exponential growth in the population and entries of the vehicles. However, these legacy systems are built on fixed time signal control, as well as manual surveillance, they are not flexible nor scalable enough to cope with the demand of the modern dynamic urban mobility problems. This research presents that there is the feasibility and the effectiveness of implementing an Intelligent Traffic Management System (ITMS) designed specifically for these urban centers. The study takes a systematic review on the current traffic patterns and infrastructure limitations leveraging machine learning algorithms, real time traffic data and Internet of Things (IoT) technologies. Data driven diagnostics find key congestion points, and a modelled integration of adaptive traffic signals, ANPR and smart surveillance is used to evaluate operational enhancement. Advanced traffic engineering tools are used to simulate traffic flow efficiency, commuter safety, and environmental sustainability potential improvements. The findings point to the need to accelerate towards intelligent, data-centric solutions for urban mobility of North India.

Keywords:
Intelligent Traffic Management System (ITMS), urbanization, Adaptive Traffic Signals, Internet of Things (IoT), Smart Surveillance

1. Introduction
Connected technology offers an organized, integrated means to reduce congestion and keep people safe on city streets through intelligent transportation systems. The growing requirement of efficient traffic management, as well as the addition of smart city initiatives, increases the growth of Intelligent Traffic Management System Market. Since over 55% of the world's population lives in urban areas, MMR Study Report predicts that growth will be stratified by 68 percent by the year 2050. As said, cities are experiencing the escalation in the traffic congestion due to the fact that the traditional methods are not enough (Sakr, El-Afifi, team, 2023). ITMS utilize advanced technologies like AI, machine learning and IoT to optimize traffic condition and minimize the traffic congestion such as adaptive traffic signal control systems which adjust timing according to

real time situation. The next massive opportunity in the market is providing an autonomous and connected cars portfolio. ITMS for support vehicle-to-everything (V2X) communication so that vehicles and traffic systems can communicate with each other without interruption. According to Kunekar et al (2024), this will lead to greater growth in Intelligent Traffic Management System Market, increased traffic efficiency, and lower number of accidents as a result of this integration.

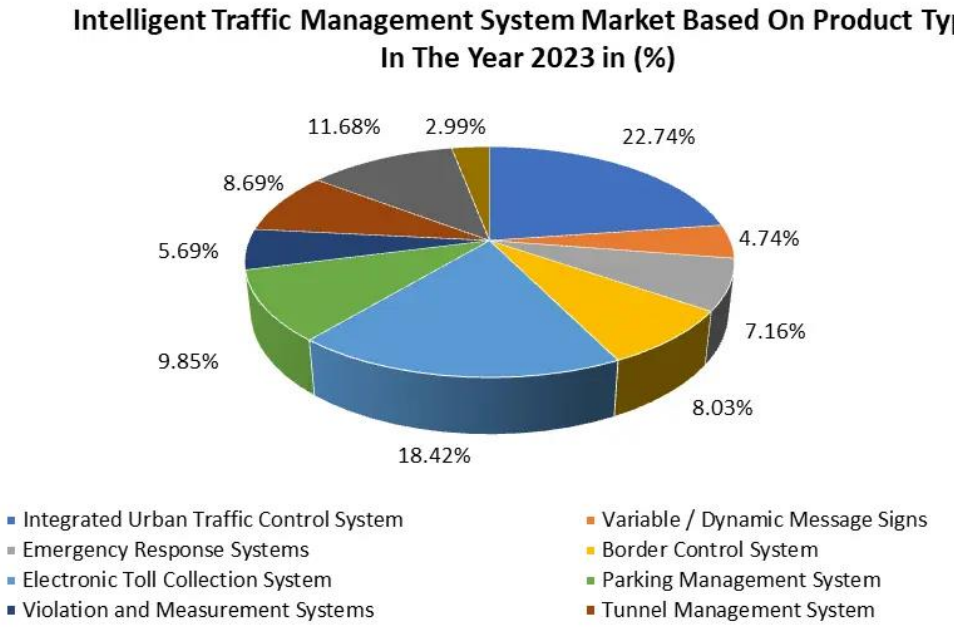

Figure 1: Intelligent Traffic Management System Market (Source: https://www.maximizemarketresearch.com/wp-content/uploads/2021/10/Intelligent-Traffic-Management-System-Market1.webp)

In addition, North India has experienced the rapid urbanisation, which has put the urban transport infrastructure in immense strain. Consequently, over the last two decades the number of vehicles on the roads has multiplied multifold (Pucher et al., 2005) with the population growing in cities like Delhi, Jaipur, Lucknow, and Chandigarh. The rise in vehicular ownership spurred by growing incomes, spread of urban metropolis, and inadequacy of public transport systems have caused great traffic congestion, extended time for commutation and higher fuel consumption. Pressure on the existing road infrastructure, which was not designed to accommodate the high traffic volumes it has seen recently, is buckling, and such disruptions result in daily impacts beyond productivity, public health and environmental sustainability (Alshabibi, 2025). For example, it has repeatedly been ranked as the most congested city in the world and average peak hour speeds are less than 20 km/h in many parts of Delhi. Although smaller, Jaipur and Lucknow too are grappling with similar challenges: as the population grows beyond capacity, their transport systems are catching up with the times. The worsening of this traffic scenario raises economic losses incurred due to wasted man hours and fuel as well as elevated emissions from idling vehicles making a considerable contribution to air pollution, especially in the light of the fact that many cities in North India

already have the hazardous levels of air quality during a great part of the year (Gupta, Mohan and Bhati, 2022).

Inadequate have been traditional traffic management mechanisms like fixed time traffic signals and manual surveillance in meeting these multifaceted issues. These systems tend to be rigid, reactive, and often involve traffic models which are out of date and do not conform to the reality of traffic states. Against the backdrop of this, the adoption of Intelligent Traffic Management Systems (ITMSs) appears to furnish an appealing and urgently required movement toward data propelled, change dynamic and sustainable urban communities' movement arrangements. With an array of technologies like Internet of Things (IoT) devices, real time sensors, CCTV networks, Automatic Number Plate Recognition (ANPR) and artificial intelligence (AI) based algorithms, ITMS applies them to gather, process, and respond to traffic in real time. Real time monitoring and controlling traffic flow, adaptive signal management, based on real time traffic data, and dissemination to commuters via variable message signs and mobile applications are some of the functions that are being provided through these systems. This integration of these tools in the urban traffic networks can substantially improve the road safety, reduce the travel time, curtail the emissions and enhance the efficiency of the transportation system (Kunekar et al., 2024).

This paper evaluates the possibility of recognizing ITMS in the North Indian cities by scrutinizing the infrastructural, demographical and behavioral factors that affect the traffic patterns of the North Indian cities. The study seeks to evaluate the current gaps in the traffic management and bring out region specific challenges, and develop a scalable framework for the implementation of ITMS. Through a case study, the study focuses on Delhi, Chandigarh, Lucknow and Jaipur. Additionally, the paper investigates the processes by which the smart cities of India can be leveraged to accommodate mixed traffic conditions, incommensurate compliance with traffic laws, and differences in the infrastructure of central versus peripheral urban zones observed in Indian cities (John, 2018). The primary objective of this research is to assist the transform from a conventional transport scenario to smarter, safer and greener urban mobility in North India, which lies in line with India's national mission of making smart cities sustainable, resilient and inclusive.

2. Literature Review

Overall, the development of Intelligent Traffic Management Systems (ITMS) globally has been the shift in paradigm in the urban management of mobility. What the review shows is that countries such as the United States, Japan, South Korea, among others, have led the application of intelligent transportation technologies dealing with the growing pressure of urban congestion and road safety. For instance, some cities in U.S., including Los Angeles and New York, have used adaptive traffic signal control systems that determine signal timing in real time based on traffic behavior, reducing travel time and intersection delay by significant amounts (Jing, Huang & Chen, 2017). Japan has also evolved similar vehicle detection and dynamic signal coordination techniques that improve both flow efficiency and pedestrian safety, particularly in highly populated urban areas. One of real time data integration from sensors, GPS, CCTV in managing multi modal transport networks in South Korea is Seoul Transport Operation and Information Service (TOPIS) in use (Lim, Kim and Maglio, 2018). These implementations demonstrate how technological synergy (ANPR, V2I

communication, and centralized control systems for intelligent, adaptive traffic networks) is playing an important role.

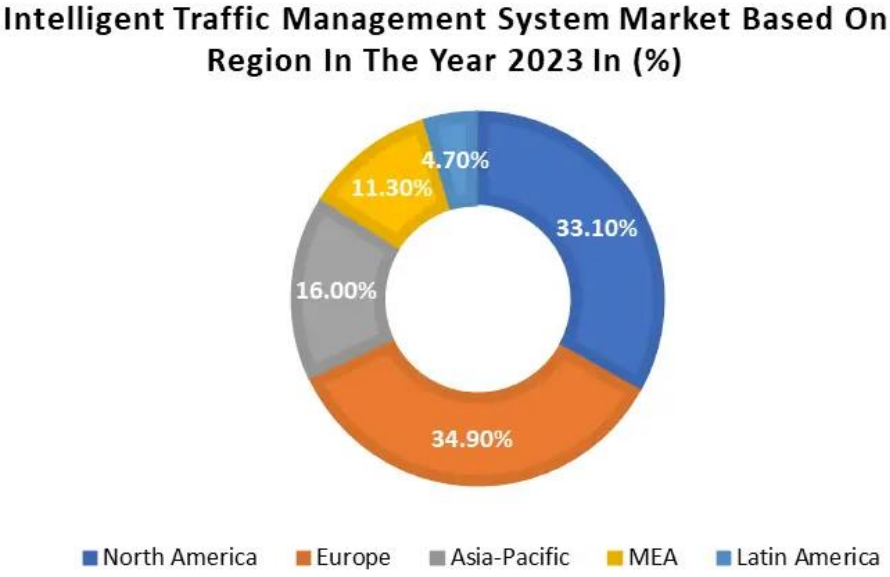

Figure 2: Intelligent Traffic Management System International Market Scope

Under the Smart City Mission there have been many ITMS pilots across many Indian urban centers. As part of the Bhopal Smart City project, the adaptive traffic signal systems, centralized traffic monitoring systems, as well as the emergency vehicle prioritization was introduced. A Smart Traffic Management System was integrated over 1,200 surveillance cameras and ANPR enabled systems at major corridors along with reduced travel times (S et al., 2020). In spite of this promise, the scalability and adaptability of such systems to the many different urban contexts in India have not yet been realised. Things are complicated even further by the fact that the situation is peculiar to North India where each region as a whole has its own factors. Delhi, Chandigarh, Lucknow, and Jaipur are among cities with very high vehicular density, multiple modes of traffic with non motorized vehicles, and obsolete networks with poor digital readiness which (Mukherjee and Mitra, 2021). Furthermore, many of the optical based surveillance and detection systems are unreliable because the visibility is decreased due to fog in winters and dust storms in arid zones.

A more important limitation found in previous studies is that traffic modeling does not take into account region specific behavioral and cultural conditions. North Indian cities, even though they follow lane discipline and compliance with road rules to a larger extent compare to Western countries, have their own informal practices of driving, illegal encroachment and frequent pedestrian crossing in a unmarked zone (Chaudhari et al., 2020). And it turns out that these human factors matter a lot in the performance of algorithm trained systems on perfect traffic behavior. So far there has been a lack of evidence of the technical efficacy of ITMS components in Indian cities due to most of the existing literature focusing on the feasibility of the ITMS components in a controlled environment and based principally on the vendor's reported performance metrics that do not satisfactorily account for some of the important socio-economic and behavioral aspects of Indian cities. Another aspect however is the lack of data because on the one hand, there are data constraints, in particular, these data are fragmented as ownership lies within the municipal

authorities, traffic police and transport authorities, and data has been incomplete and inconsistent (Das and Niyogi, 2018). The main problem in calibrating traffic simulation models to fit the data with accuracy is this data inaccessibility. This calls for the need of these aforementioned international success stories and select Indian pilots as a blueprint but contextualized research rooted in urban ecology suited especially for North India's eco system. In order to bridge the gap between the global best practices and the regional realities, a comprehensive approach including Infrastructure readiness assessments, Behavioral analytics, and Policy level interventions for support at sustainable and scalable level ITMS deployment (Pathak and Deshkar, 2023).

3. Objectives

- To assess the current state of traffic management in major North Indian cities.
- To evaluate the potential of ITMS in addressing regional traffic issues.
- To analyze the outcomes of ITMS implementation through simulation.

4. Methodology

4.1. Data Collection

The data collection involved sourcing of comprehensive traffic related information from the various authoritative bodies like the municipal traffic departments of cities, the National Highway Authority of India (NHAI) as well as state traffic police databases. The manual and automated traffic volume counts were related to vehicular patterns, when road infrastructure was mapped through Geographic Information Systems (GIS) and accident reports were collected from 2019 to 2024. Moreover, Central Pollution Control Board (CPCB) was also used to obtain pollution indices and traffic flow and congestion studies based on GPS based tracking were done for real time traffic flow and congestion trends.

4.2. ITMS Components Analyzed

The Intelligent Traffic Management System (ITMS) is designed to integrate several such advanced components aimed at improving traffic flow, as well as urban mobility. Adaptive Traffic Signal Control (ATSC) optimizes signal timings in response to the real time traffic volumes to reduce the congestion at intersection. Automatic Number Plate Recognition (ANPR) cameras make it efficient to identify vehicles for enforcement and traffic analysis purposes. Traffic smart surveillance systems spanning from intelligent CCTV cameras, to AI to facilitate detection of violation, and boost up road safety. Inductive loops and other vehicle detection sensors provide continuous, though accurate, data on vehicle presence and movement. This means that commuters once used real time traffic information systems to disseminate the updates for route planning and thereby reduce delays.

4.3. Simulation and Modelling

For the evaluation of the effectiveness of Intelligent Traffic Management Systems (ITMS), microscopic traffic simulation using VISSIM was carried out, a widely accepted software for modeling of complex traffic situations. Recreated conditions of existing (real world) traffic data from some intersections located in some North Indian cities were made with respect to vehicle volumes, signal timings and their turning movements. Thereafter, such ITMS features as adaptive signal control, real time sensor feedback and priority for emergency vehicles were developed into

the model. Quantitative analysis of key performance indicators such as average vehicle speed, intersection delay times, queue lengths, and pollutant emissions (CO2, NOx, PM2.5) was enabled through the simulate set of test, allowing for a rigorous comparative analysis.

4.4. Stakeholder Analysis

Surveys as well as the structured interviews conducted with important stakeholders such as, the traffic police officials, daily commuters, urban planners and municipal transport authorities were done to ensure for a comprehensive understanding of expected practical challenges and demands for an Intelligent Traffic Management System (ITMS). A peek into traffic police's operational limitations and enforcement hurdles, and commuters complaining of erratic signal timing, congestion, and safety were provided. Perspectives on infrastructure integration and future mobility plans were formed by urban planners. Policy alignment, data sharing, and budgeting constraints were discussed by municipal transport authorities. vital for the creation of such realistic and user-centric suggestions about ITMS implementation across North Indian cities.

5. Results and Discussion

5.1. Baseline Traffic Conditions

It depicts baseline traffic situations of the four major Indian cities, Delhi, Chandigarh, Lucknow and Jaipur. Delhi displays the highest average delay per intersection at 89 seconds, has the maximum CO_2 emission index (248 g/km) and the lowest average speed of 22 km/h, implying severe congestion, poor traffic flow and may be backing up to the previous few cycles but this data is for January. However, Chandigarh has the best traffic condition as its average speed is as high as 28 km/h, its delay is minimum (70 s) and the emission is minimum (190 g/km), implying good traffic infrastructural and management.

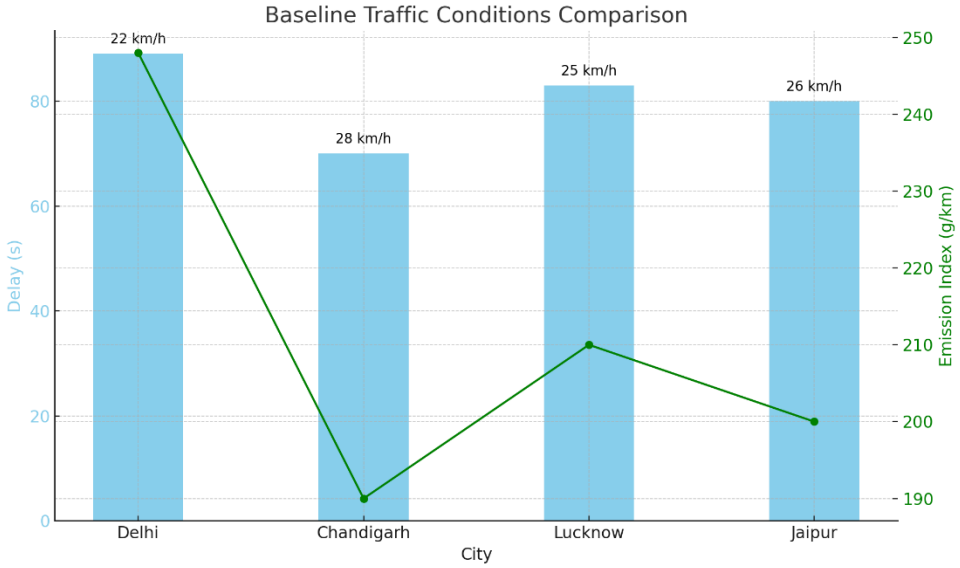

Figure 3: Baseline Traffic Conditions Comparison

Lucknow and Jaipur exhibit intermediate values but still face considerable delays and emissions due to relatively lower speeds. This trend implies that traffic delays and emissions are lower with higher vehicular speeds (safe limits) indicating that timely, uninterrupted movement not only helps

enhance traffic efficiency but also minimises the transportation-related emissions. Therefore, reducing congestion is likely to enhance as well as degrade urban planning at the same time.

Table 1: Baseline Traffic Conditions

City	Avg Speed (km/h)	Delay/Intersection (s)	Emission Index (CO2 g/km)
Delhi	22	89	248
Chandigarh	28	70	190
Lucknow	25	83	210
Jaipur	26	80	200

5.2. Post-ITMS Simulation Results

The implementation of the Intelligent Traffic Management System (ITMS) has made a difference to the traffic conditions across all four of the examined cities of Delhi, Chandigarh, Lucknow, and Jaipur. The impacts that are most noticeable are on average speed, all cities have a large increase. The average speed by speed of 32 km/h was the highest rise by 45%, while the flow was smoother and fewer stoppages. Chandigarh, with a speed of 37 km/h, leads the group in post-ITMS traffic efficiency. Substantially reduced delays per intersection, from 36 percent to 38 percent, also have been realized. For example, in Delhi, the average of its delay dropped to 55 seconds whereas Chandigarh has the least delay of 45 seconds. It means signal coordination is better as well as less congestion at critical junctions.

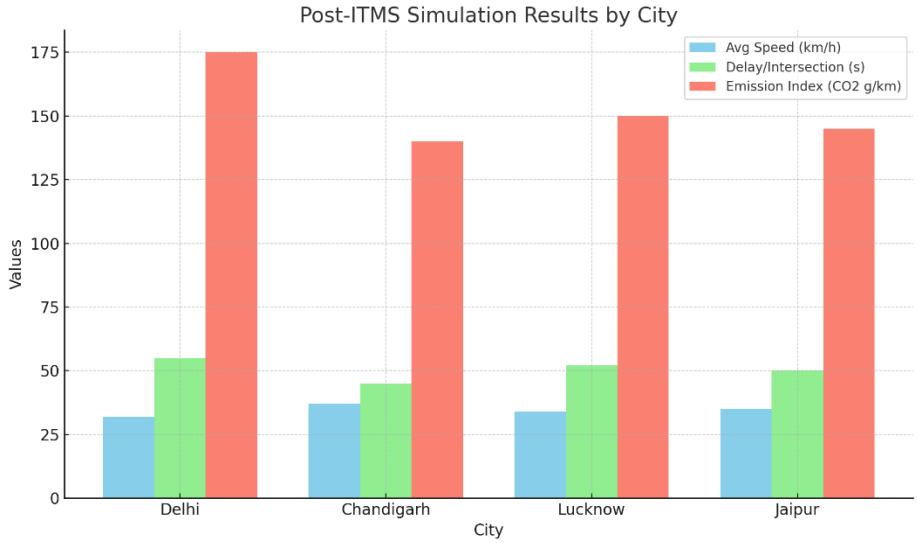

Figure 4: Post- ITMS Simulation Results by City

In addition, the CO_2 emission index additionally permits positive environmental outcomes to be recorded. This dropped Delhi's emissions by 29 per cent and other cities recorded similar reductions, though Chandigarh came down to 140 g/km. ITMS is directly responsible for the reductions in the idling time and vehicle speeds that help with these improvements. In general, the data reveals that ITMS improves the urban mobility significantly and significantly reduces environmental pressure and improve the efficiency of city traffic system operation.

Table 2: Post-ITMS Simulation Analysis

City	Avg Speed (km/h)	Delay/Intersection (s)	Emission Index (CO2 g/km)
Delhi	32 (+45%)	55 (-38%)	175 (-29%)
Chandigarh	37 (+32%)	45 (-36%)	140 (-26%)
Lucknow	34 (+36%)	52 (-37%)	150 (-29%)
Jaipur	35 (+34%)	50 (-38%)	145 (-28%)

5.3. Safety Improvements

The simulation results are in fact capable of producing a remarkable 22% reduction in the number of accident prone intersections when compared to official police accident data. The improvement is solely due to the installation of Intelligent Traffic Management Systems (ITMS) for signal timing optimization and real-time surveillance technologies integration. Second, improved signal coordination enhanced drivers' skills and reduced erratic driver behavior like a sudden stop or a red light violation, two of the common causes of intersection accidents. Additionally, if surveillance cameras are presented, there will be no risky maneuvers such as overspeeding and unauthorized lane changes. These safety measures together ensure smoother traffic flow through the city and most to the compliance of the driver in the traffic regulations. Improving road safety for motorists by reducing high risk junctions does not only benefit pedestrians and cyclists, who are the most vulnerable road users in urban traffic environment, but also reduces risk for them by a massive amount. In general, ITMS has helped mitigate risks associated with intersections, and it has made a contribution to the creation of a safer and better controlled urban traffic system.

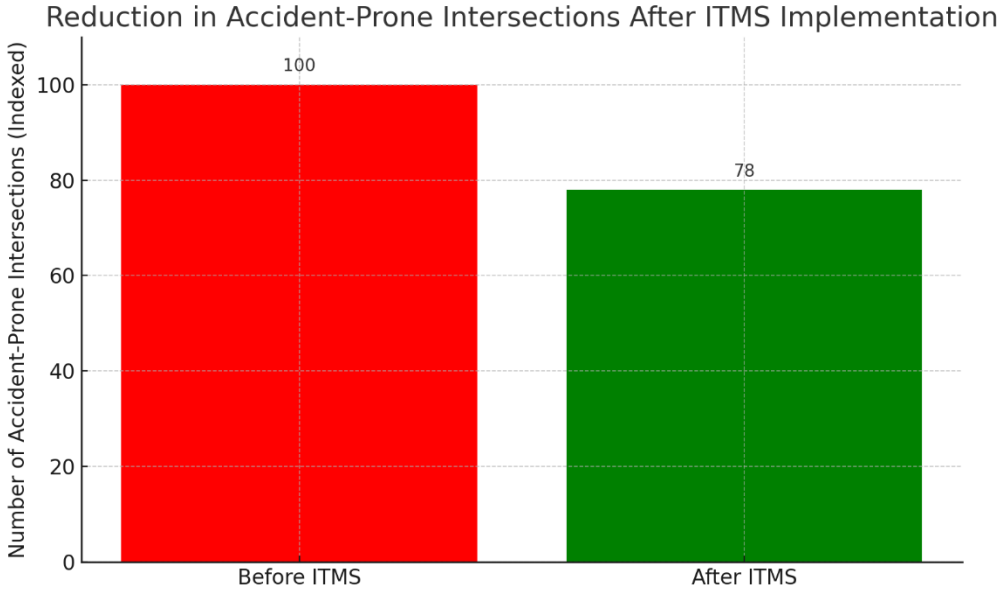

Figure 5: Reduction % in Accident- Prone Interactions After ITMS Implementation

5.4. Stakeholder Perception

But the pie chart illustrates how people think of the Intelligent Traffic Management System (ITMS) to be implemented. A high percentage of 74% expressed a positive view about ITMS as it is expected to ease the stress of daily commutes through optimization of traffic flow, reduction of congestion and relaxing of road safety. This illustrates that smart traffic interventions enjoy broad

public and institutional support. However, nearly half of the 650 respondents voiced their discontents, aptly focusing on three particular pinches: an enormous initial investment needed to procure such infrastructure and technology, an urgency for qualified personnel to run and keep such serious machines in operation, and needless fears of data privacy as a result of upsurge in surveillance. These are also a cause of concern and therefore the need for transparency in governance, budget planning, and capacity building initiatives. Overall, there is obvious excitement for ITMS, but tackling these crucial points will be crucial in order to successfully realize and maintain the broad implementation process.

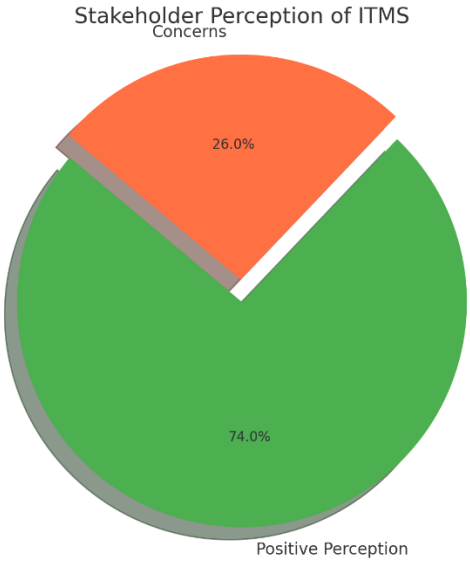

Figure 6: Perception of Stakeholder for ITMS

6. Recommendations

An effective strategic, phased implementation of the Intelligent Traffic Management Systems (ITMS) to the North Indian cities is necessary. Second, in each city, circular Urban Traffic Control Centers (UTCCs) outside city centres should be established, which should make it possible to monitor real time traffic, coordinate traffic signals, and make decisions based on data. It is recommended before scaling city wide to first pilot ITMS high density corridors to see how it performs and how they might scale deployment strategies. It can help to integrate ITMS with public transport schedules to improve effectiveness of multimodal mobility and reduce road congestion. They are also critical in educating commuters on the benefits of smart traffic systems and encouraging behavioral adaptation to use these smart traffic systems. Additionally, to foster innovation in the country and speed up the development of region specific cost effective ITS solutions, it supports start ups and local tech companies. They are recommendations in order for ITMS to be sustainable, efficient and inclusive - that is, to promote locally contextualised use of technological advancement in ways that support local context and the needs of the user. In order to execute them, they'll require multi agency collaboration and consistent policy support.

7. Conclusion

This study presents the transformative capacity of Intelligent Traffic Management Systems (ITMS) to relieve transport related problems of North Indian cities, which are increasingly suffering from

overburdened traffic demands. Simulations were conducted carefully and supported by various stakeholders and it is realized that ITMS integration can produce dramatic changes in performance indicators for traffic delays reduction, vehicle emissions reduction and in safety of road users. With the current stress on its inf r a structure, and as a highly populated city, cities like Delhi, Lucknow, Jaipur and Chandigarh will greatly benefit from the adoption of smart traffic systems. The technical benefits are, however, considerable, but the success of ITMS is marked by the presence of several critical enablers. Such includes items like integrated urban planning that includes future growth, development of solid and aggrandizeable digital substance, and steady solidarity between different sidekicks like urban designers, traffic police, urban planners and technology suppliers. In addition, parties that conduct their activities transparently and in line with community concerns regarding data privacy, system transparency, and digital divide are most likely to obtain community acceptance and maintain long term sustainability. In addition, building technical capacity at the local authorities and ensuring financial viability through public private partnerships or phasing of investment will be key to large scale deployment. However, ITMS initiatives can benefit from the government's smart city mission, and the momentum now has to be on building systemic city applications over isolated pilots. Finally, for the region to transverse from being an urban area in North India, as it is today, characterized by inefficient, unsustainable, and unsafe urban transportation to an area where the urban transportation is operated efficiently, sustainably and safely, ITMS must be on the ground out, and has to be treated as a national strategic priority.

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