ISSN: 2633-4828 Vol. 5 No.2, June, 2023

International Journal of Applied Engineering & Technology

ECONOMIC AND SOCIAL IMPACTS OF TRAFFIC CONGESTION IN GURUGRAM: A COMPREHENSIVE ANALYSIS AND PROPOSED SOLUTIONS

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ABSTRACT

The necessity of traffic control is essential for the maintenance of order, safety, and productivity on road networks and in urban areas. Its applicability spans a range of societal characteristics, from the promotion of public welfare to the maintenance of ecological equilibrium. The focus of this research study is a thorough examination of the economic and environmental effects of traffic congestion in the Indian city of Gurugram, located in the state of Haryana. The paper focuses primarily on a comprehensive examination of the negative effects on productivity, commercial expansion, and air quality, as well as a discerning evaluation of several potential mitigation solutions. Using a synthesis of factual data, in-depth case studies, and policy evaluations, this paper identifies a pressing need for Gurugram to adopt sustainable mobility management paradigms as a top priority.

Keywords: Traffic congestion, Gurugram, economic impact, environmental impact, public transportation, sustainable solutions.

1. INTRODUCTION

Traffic control is crucial for sustaining order, public safety, and productivity in urban contexts, influencing several elements of society, from the environment to the well-being of the general populace (Khanna & Chauhan, 2023). Effective traffic regulation is essential for efficient and secure transportation, affecting urban life, health, and economic growth beyond road safety. For effective traffic management, collaboration between government entities, urban planners, law enforcement, and the public is essential. Rapid urbanisation and commercial expansion in Gurugram have resulted in increasing traffic, which has impacted both the local economy and ecosystem. As a rapidly expanding city in Haryana's National Capital Region (NCR), Gurugram's population has increased from 10.08 lakh in 2011 to 16.82 lakh in 2019, and is anticipated to reach 42.5 lakh by 2031, under the GMUC Development Plan. "Millennium City" is home to 250 Fortune 500 companies and is a hub for software, IT, and outsourced services. Despite these economic advancements, traffic congestion offers significant obstacles, extending work hours, increasing prices, and inhibiting investor participation. Due to traffic congestion, increased emissions, air quality issues, and carbon dioxide emissions are observable. Noise pollution and poor infrastructure require immediate attention for the health of the community. The report reveals several traffic issues, such as insecure pedestrian pathways, limited bicycle utilisation, and a shortage of lanes allocated to non-motorized vehicles. Inadequate coordination and infrastructure for public transportation exacerbate the traffic situation, especially between Gurugram, Delhi, and Faridabad (Kumar & Chadchan). To overcome these obstacles, structured parking options, improved traffic management, and increased stakeholder participation are required.

A literature review on traffic control would involve summarizing and analyzing existing research, studies, and publications related to various aspects of traffic management, including traffic signals, road signs, congestion management, traffic flow optimization, and more (Wu & Sun, 2022; Hurter et. al., 2010; Wiering et. al., 2004; Nair & Cai, 2007). Research on the optimization of traffic signal timing to reduce congestion, improve traffic flow, and decrease travel time. This could involve methods like adaptive signal control, coordinated signal timing, and intelligent transportation systems. Examination of mathematical and simulation models used to study traffic flow, congestion, and their dynamics. This could include exploring models like the LWR (Lighthill-Whitham-Richards) model or the cell transmission model (Xu & Luo, 2022; Pham et. al., 2020). Reviewing studies on the

implementation and effectiveness of ITS technologies, such as real-time traffic monitoring, predictive traffic analytics, and dynamic traffic management. Reviewing how urban planning and design influence traffic management, including mixed land use, transit-oriented development, and road network design (Azimirad et. al., 2010; Ghosh & Parisini, 2022; Deniz et. al., 2022). Studying the environmental effects of traffic control measures, including strategies to reduce emissions, improve fuel efficiency, and promote sustainable transportation (Fallahi et. al., 2016; Initiative et. al., 2012; Authority et. al., 2009).

2. DATA ANALYSIS

953 kilometers of expressways, arterials, sub-arterials, and collectors were inventoried. 31% of roads have a right-of-way under 15 meters, while 26% exceed 45 meters. 32% of roads are two- and four-lane. Speed and delay testing show that 51% of the network's length has speeds below 30 km/h and 11% surpasses 60 km/h. NH-48, formerly NH-8, is crowded. Traffic dynamics in Gurugram generate 4,47,519 and 4,49,722 PCUs (Sehrawat & Chawla, 2023). According to traffic trends, 75% of intercity transportation is between external and internal locations, whereas 25% is external-to-external (Pathak & Kumar, 2020). Alternate regional road connections are needed to reduce through traffic. The research region has 21,880,000 intra-city motorized trips and a projected population of 16,820,000 in 2019. Walking journeys increased 33%, while public transit and work-related travels increased 9 and 57%, respectively. Private cars, poor intracity transit services, and intercity travel cause traffic and environmental issues (Khanna & Chauhan, 2023). Intercity traffic, especially Gurugram-Delhi routes, requires road capacity and public transportation improvements. In 2018, the Delhi Metro yellow line carried 2,80,540 passengers and the Rapid Metro 61,000. 21 of 28 Haryana Roadways and private buses carried 96,363 passengers daily. The 41 percent of Gurugram workers who use public transportation, including the IPT system, need immediate improvements (Saxena & Choudhury, 2022). The Gurugram Bus Stand serves 19,324 passengers daily, with 1,416 peak-hour arrivals and 622 departures. The station handles 30,080 rush-hour passengers. (https://shaktifoundation.in/wp-content/uploads/2017/06/WRI-2015-India-Specific-Road-Transport-Emission-Factors.pdf)

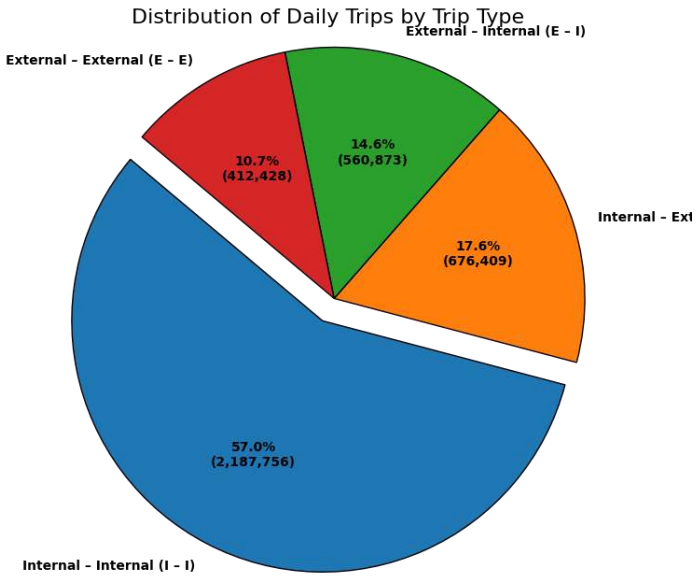

Figure 1 *Gurugram Travel Demand (Motorized Trips), 2019*

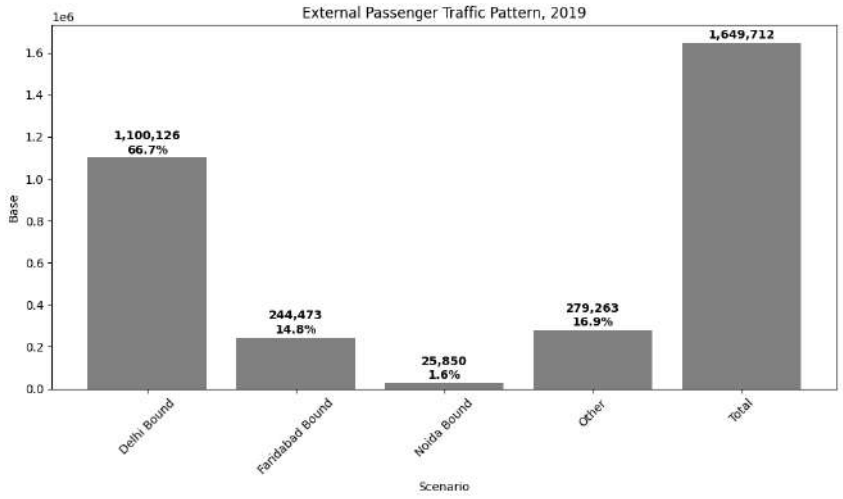

Figure 2 *External Passenger Traffic Pattern, 2019*

2.1. Gurugram Accidents

Over speeding and negligent city driving cause most accidents. Overspeeding causes 43.5 percent of city accidents, while irresponsible driving causes 39.8 percent. Figure 3 illustrates the city's accident cause % (Chamola et.al., 2023; Devi & Kumar, 2018; Tawar et. al., 2018).

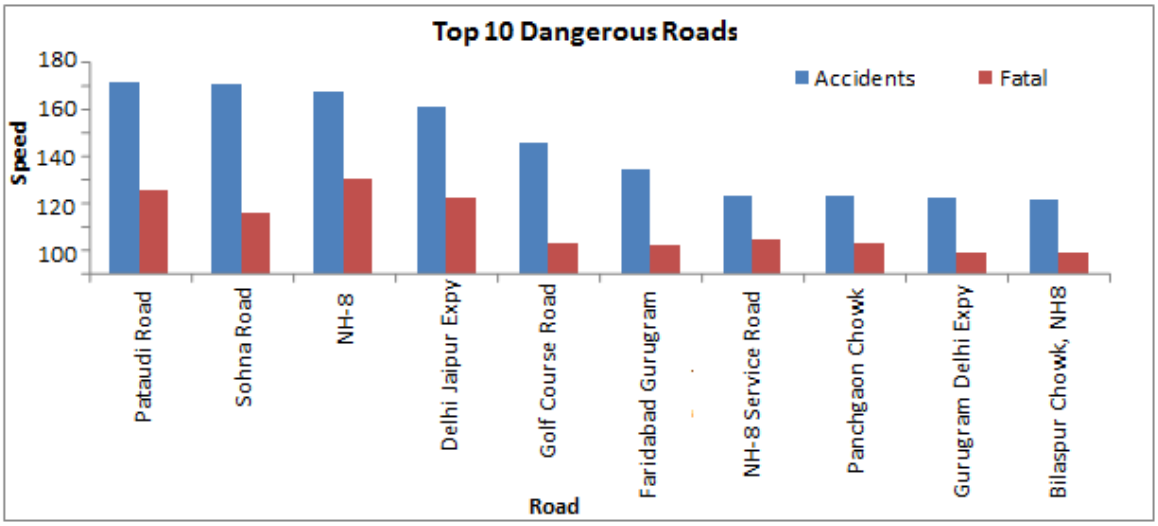

Figure 3 *Gurugram's top 10 risky roads' accidents and deaths*

About 62% of incidents happened between 6PM and 6AM, when road users may reach the network's maximum speeds, which may be one of the main reasons for over-speeding in the city and suggests speed zoning/limits. Accidents by time are shown in Figure 4.

Better patient outcomes and fewer long-term effects can be achieved through prompt diagnosis and treatment. Though India conducts a lot of studies, relatively few of them centre on rural communities. Between 54 and 60 million people per year are estimated to sustain a traumatic brain injury (Chamola et al., 2023; Gadre et. al., 2013). One of the leading causes of death or permanent disability is brain injuries. According to Pauvanachandra and Hyder, one million people in India need rehabilitation after suffering a traumatic brain injury (Patil et. al., 2018; Zandi and Seyed, 2013)

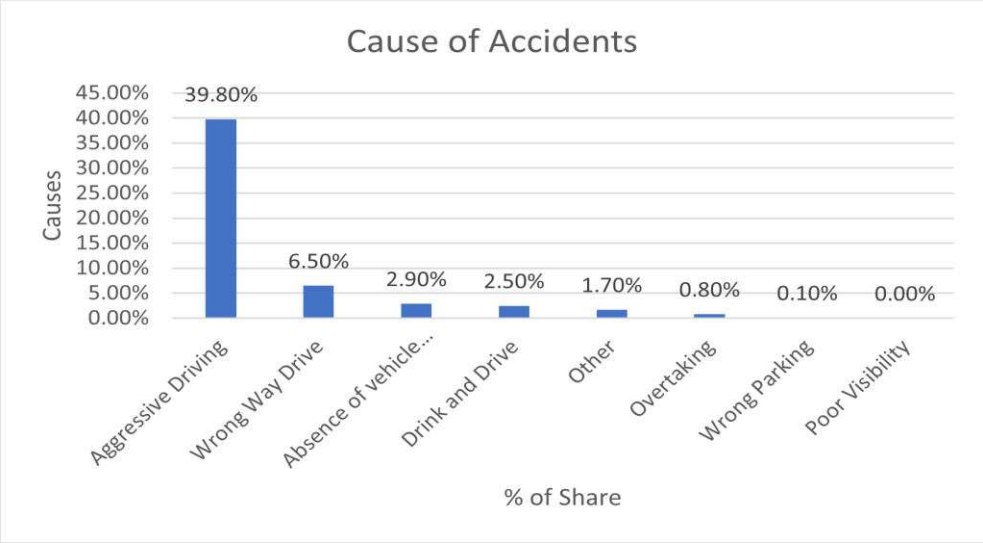

Figure 4 *Cause of Accidents*

3. Transportation Improvement Plans

This extensive research examines bus and metro system expansion and dedicated lanes for non-motorized transport. Intelligent traffic management, real-time monitoring, and signal synchronization are examined to optimize traffic flow. Carpooling incentives, ride-sharing, and remote work policies reduce congestion. Road expansions, flyovers, and urban design affect traffic management (Malcoti et. al., 2023). The study also evaluates peak-hour congestion pricing. To reduce transportation-related air pollution and carbon emissions, electric vehicle promotion is considered.

3.1. Regional connectivity

OD figures show Gurugram workers travel to Delhi, Faridabad, and Noida daily. Regional connections are needed to improve public transit. Gurugram's metro connects HUDA city Centre to Delhi. Approximately 66% of passenger travel is Delhi-bound, emphasising regional links with Delhi. Table 3 shows regional direction forecasts. Table 4 estimates daily and peak-hour outer cordon traffic.

Table 3. Directional regional passenger flow of base and horizon year

Scenario	Delhi Bound	Faridabad Bound	Noida Bound	Other	Total Passenger Trips
Base	1100126	244473	25850	279263	1649711
HY 2041	3300379	733418	77549	837788	4741022
% Share	66.7%	14.8%	1.6%	16.9%	100.0%

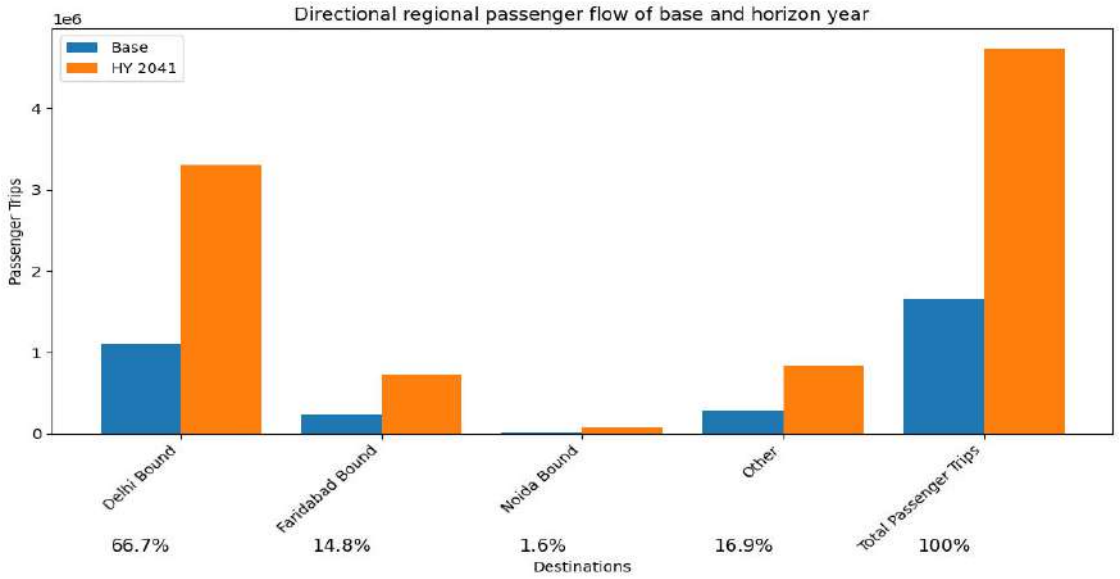

Figure 5 *Directional regional passenger flow of base and horizon year*

Table 4. Location wise Traffic forecast at Outer Cordon

		BY 2019			BAU HY 2040		SC4 HY 2041	
S. No	**Location**	**Daily (PCU)**	**Peak Hour Volume**	**Peak Share**	**Daily (PCU)**	**Peak Hour Volume**	**Daily (PCU)**	**Peak Hour Volume**
1	Delhi – Jaipur Expressway	161206	11989	7%	462661	34408	371701	27644
2	Farukh Nagar Road	18194	1186	7%	52217	3404	43727	2850
3	Pataudi Road	18091	1226	7%	51921	3519	41057	2782
4	Faridabad Road	73419	5789	8%	210713	16614	145404	11465
5	MG Road	113905	8821	6%	326907	25316	262223	20307
6	Old Delhi – Gurugram Road	63632	4754	7%	182624	13644	149752	11188
7	Najafgarh – Kapasheda Road	29986	2354	8%	86060	6756	68957	5413
8	Sohna Road	54477	3879	7%	156349	11133	115698	8238
9	Rezang – La Marg	14947	1229	8%	42898	3527	34879	2868

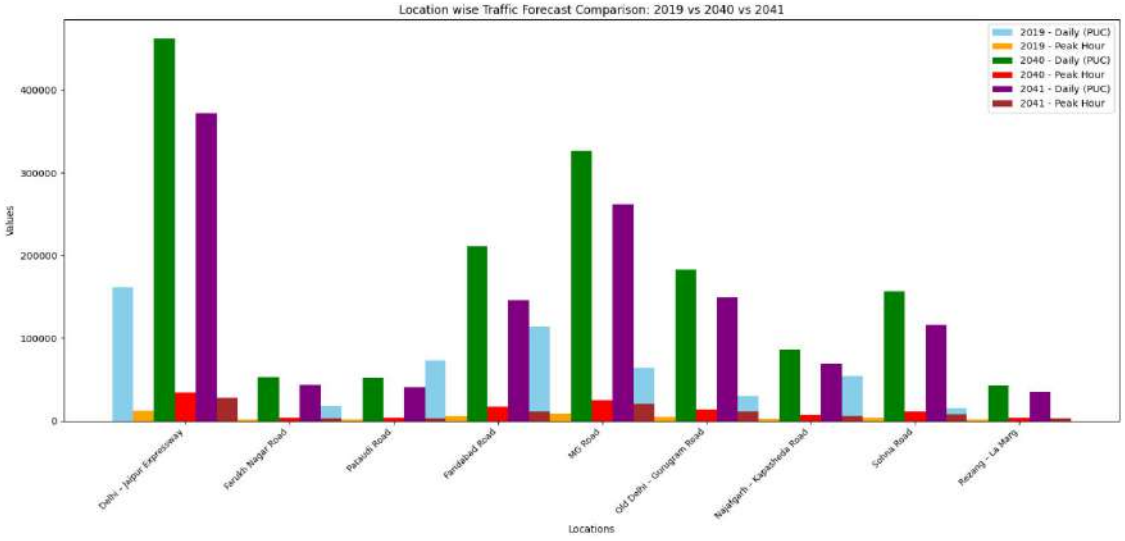

Figure 6 *Location wise traffic forecast comparison 2019 vs 2040 vs 2041*

3.2. Regional road connections

Due to increased traffic, NH-48 and MG Road, Delhi's main regional roads, need improvement. Regional connectivity requires Delhi-Gurgaon improvements. The Dwarka Expressway connection gap between Delhi UER-II and NPR Road in Gurugram, Sector 115/114-108/106, a 1.40KM gap in the Old Delhi-Gurugram route from NH48, a 3.0 KM gap in NPR Sector 114, and the Nelson Mandela Road to MG Road connection are among the gaps. The road network relies on the Outer Ring Road, including GSPR.

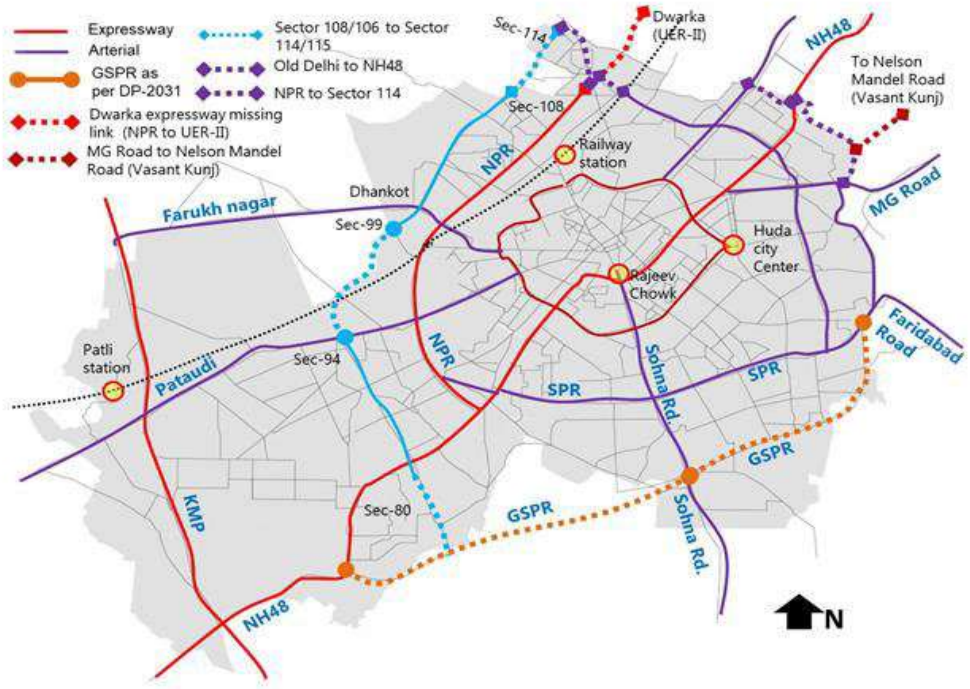

Figure 7 *Proposed Regional Road network.*

3.3. Active Transport

The active transportation strategy of the CMMP Gurugram focuses on boosting walkability and cycling in the city to increase cycling share to 15% by 2041 while keeping the walk share at 33%. Improving footpath accessibility is essential, as only 28 percent of the network currently has walkways, resulting in pedestrian safety issues and traffic congestion caused by encroachments and automotive use. The concept involves adding pathways with a width of 1.8 metres to about 1,300 miles of the road network, creating a safer environment for pedestrians and addressing the pressing need for growth in specific corridors.

Table 5. Proposed footpath network length

	Existing	Phase 1	Phase 2	Phase 3	Total Footpath
Length (in Km's)	153.6	151.6	168.7	609.1	1083
Share (%)	14.2%	14.0%	15.6%	56.2%	100.0%

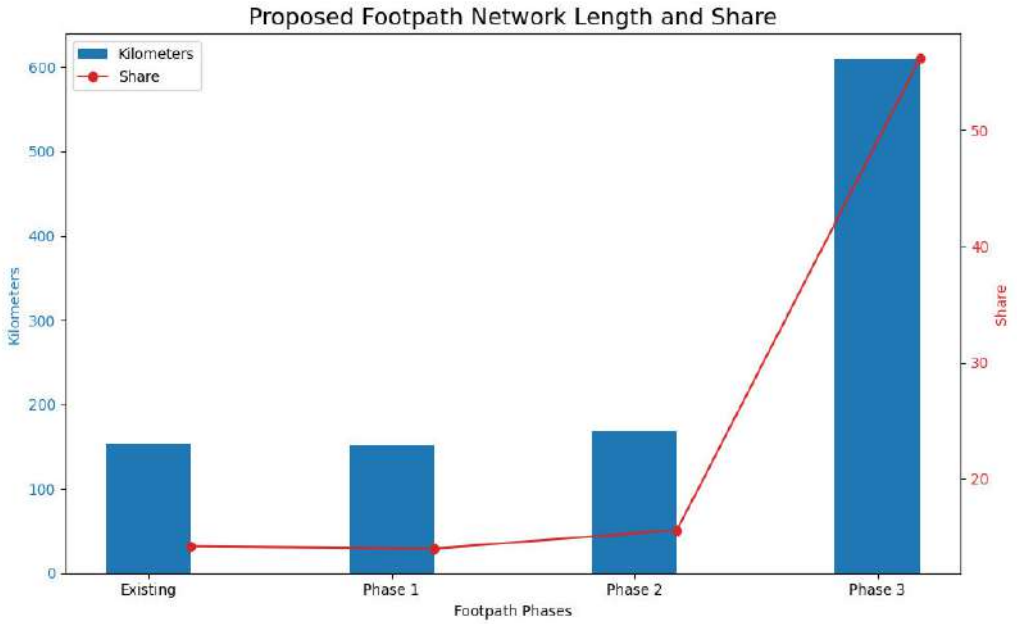

Figure 8 *Proposed footpath network length and share*

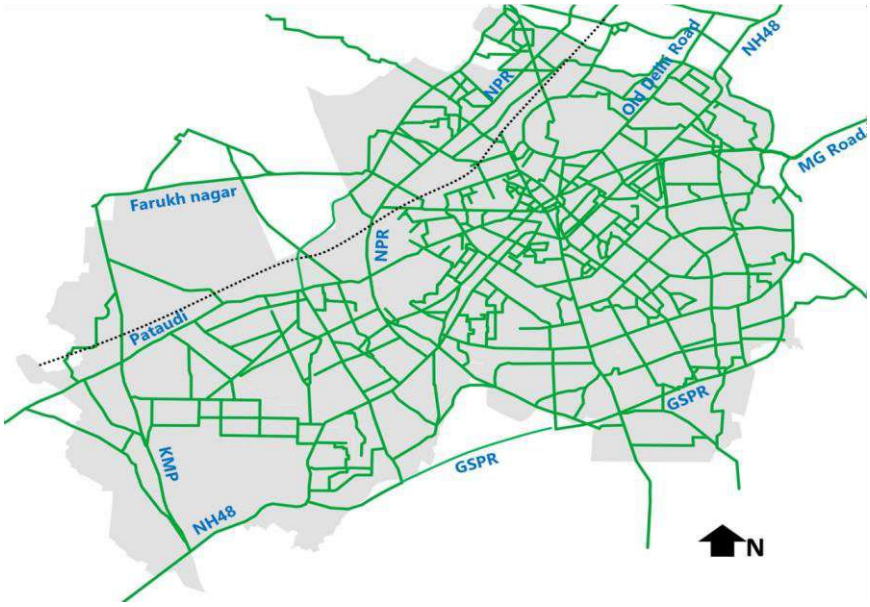

Figure 9 *Proposed footpath network.*

The clear walkway width, ideally between 1.8 and 2.5 meters with a kerb height of no more than 150 mm, and signal phases at each intersection depend on available land. 3MLCP in Kaman Sarai, behind the Post Office, near Jama Masjid, and Sikanderpur Road have pedestrianization potential. Plan 2 emphasizes secure pedestrian crossing facilities since inadequate infrastructure might hurt municipal transit and ridership. Traffic flow, waiting time, vehicle speed, road accident data, and user behaviour are considered in IRC:103-2012 implementation. The study proposes 17 pedestrian crossing facilities in Phase 1, 40 in Phases 2 and 3, and FOB sites depending on project findings and public comments.

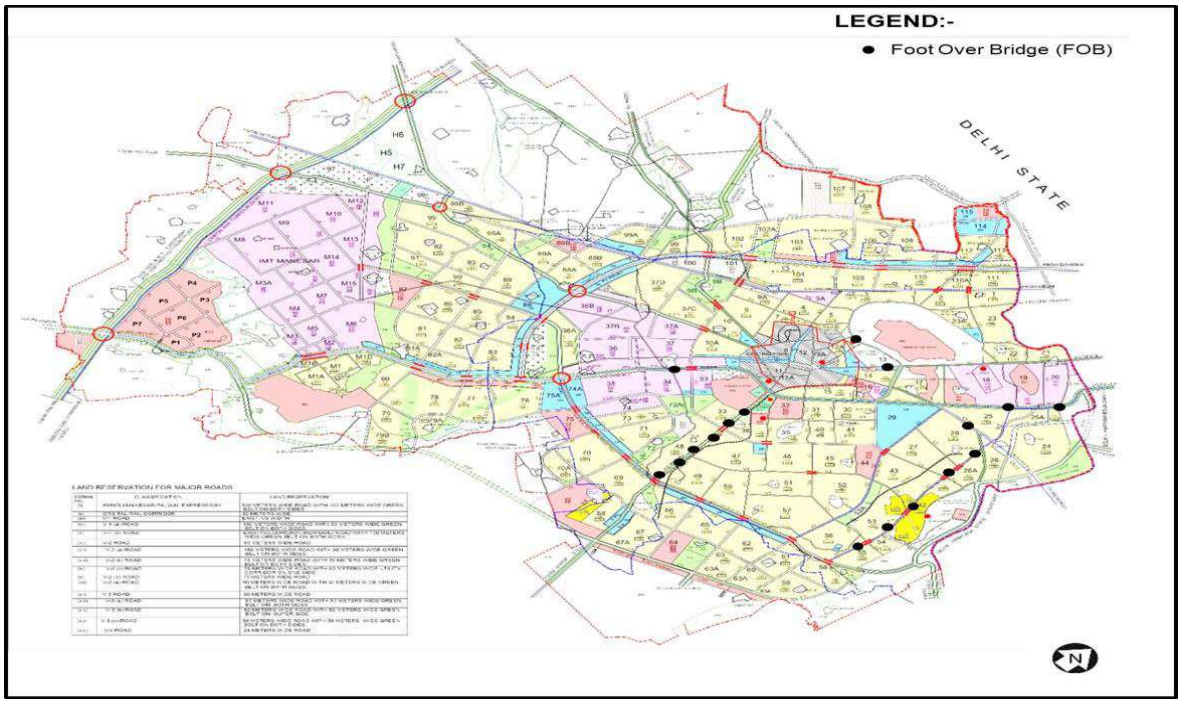

Figure 10 *Phase 1 proposed pedestrian crossing facilities*

3.4. Public Transport

The 2017 DIMTS study "Implementation of City Bus Service Project in Gurugram — Bus Route Planning and Rationalization" recommended immediate bus route changes. The present research's horizon year projections are like the DIMTS analysis, with minor phasing adjustments depending on estimated ridership for the proposed routes (Goil and Gupta, 2016). The DIMTS research and GMCBL's current bus routes are used to create and rationalize bus routes based on predicted ridership. Table 7 shows Gurugram's PBS development phases, which organize route enhancement.

Table 6. Phasing Proposed for DIMTS Suggested Bus Routes

C	Demand per Bus	Phasing
Ambience mall to Bus Depot	800 to 1250	Operating
Basai Chowk to Huda	Less than 800	Phase – 1.1
Cyber hub to Badhushapur	Less than 800	Phase – 1.2
Dunadahera to Sector 56	Less than 800	Phase – 1.2
Dundahera to Wazirpur	Less than 800	Operating
Farukh nagar to GBS	Less than 800	Phase – 1.2
GBS to Ansal university	Less than 800	Phase – 1.1
GBS to Guru dronacharya	800 to 1250	Phase – 1.1
GBS to Palam Vihar	Less than 800	Operating
GBS to Bhondsi	Less than 800	Operating
Huda City Center to Basai	Less than 800	Operating
Huda city to Palam Vihar	Less than 800	Phase – 1.2
Huda to Bhondsi	Less than 800	Operating
Krishna Chowk to Sec 56	800 to 1250	Operating
Loop Route	Less than 800	Operating
Manesar to Railway	Less than 800	Phase – 1.1
Sec 88A to Palam Vihar	Less than 800	Phase – 1.2
Sec 97 to Badhushapur	Less than 800	Phase – 1.2
Sikendrapur to Sec 84	800 to 1250	Phase – 1.1
Wazirabad to Daultabad	Less than 800	Operating

Table 7. Proposed Development Phases for PBS in Gurugram

Phase	Sub - Phase	Location
Phase – 1	Phase – 1.1	First PBS development surrounding metro stations for Last Mile connection.
	Phase – 1.2	PBS expansion to metro station activity centres.
Phase – 2	Phase – 2.1	PBS development near anticipated metro corridor stations and other transit centres.
	Phase – 2.2	PBS to significant activity centres near prospective metro routes and other mobility hubs.
Phase – 3		PBS expansion to additional city regions, especially major residential districts, for maximum coverage.

Gurugram's short-term development plan expects 500 buses after route optimization and 10 additional routes (Sharma & Indu, 2019). Figure 6 highlights short-term public transit route improvements. (Some routes are functioning).

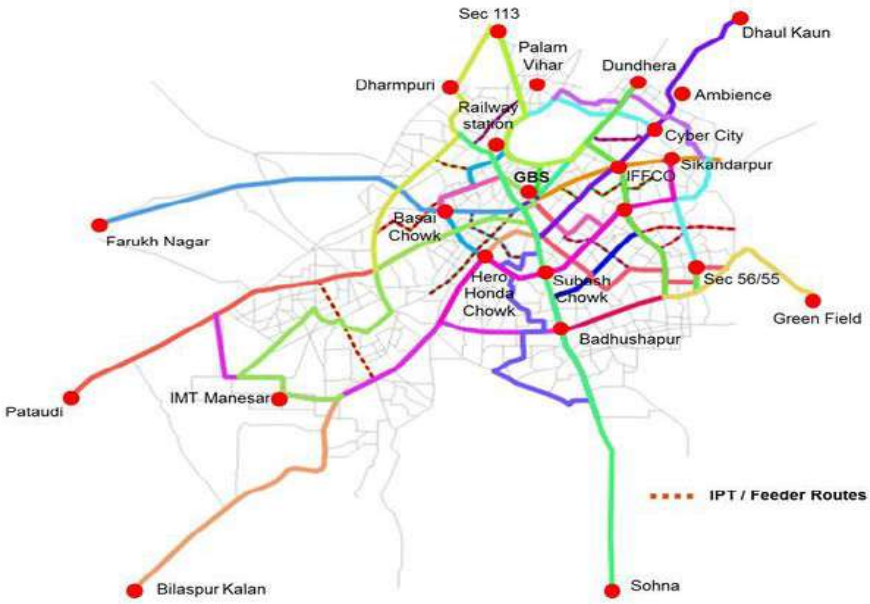

Figure 11 *Proposed bus routes under the short term enhancement plan*

CMMP aims to make Gurugram's public transportation eco-friendly, secure, efficient, and accessible while increasing its modal share from 14% to 60%. This inclusive method improves accessibility for all GMDA Area social groups. Key improvements include expanding service coverage so that 80% of residents are within 500 metres of transport options, increasing the city bus fleet to 0.35 buses per 1000 people, reducing waiting times, implementing efficient multi-modal interchanges, improving mode reliability and information dissemination, and seamlessly integrating ticketing systems. After this, each objective's tactics are detailed (Puvanachandra and Hyder, 2013).

4. Action Plans and Strategies

Urban attractions need good public transit. Gurugram's best transit system was built by analysing city structure, route alignment, and type. Demographic and job projections were used to assess public transit options, following National Transport Development Policy Committee recommendations. Gurugram's 14% PT share and modal transition necessitate reliability and intensity improvements (Hyder et. al., 2007). To promote green cities, the plan includes increasing Mass Rapid Transit System lines, introducing electric buses, and creating bus priority lanes. Phase 2 adds a medium-capacity Mass Rapid Transit System to connect vital hubs like the HUDA city centre and Cyber hub to high transit loads. The study supports the RRTS between Delhi, Gurugram, and Alwar and the Metro route from HUDA city centre to Panchgaon. The projected 197-kilometer public transportation network includes a 34.65-kilometer Gurugram RRTS segment.

Table 8. Criteria for Choice of the Mode of Mass Rapid Transit System

Mode Choice	PPHPD	Population (Millions)
Metro Rail	>= 15000 for at least 5km continuous length in a corridor	>= 2
LRT Primary at grade	=< 10,000	> 1
Monorail	=< 10,000	> 2
Bus Rapid Transit System	>= 4,000 and Up to 20,000	> 1

Traffic and inventory studies inform Gurugram's road upgrading plan. The base year traffic assignment capacity assessment found many route linkages for growth. Horizon year traffic assignment determines committed and

planned widening and grade separation projects. These include intersection improvements, six-lane road enhancements, and junction redesigns for pedestrian and bike amenities. Roadways follow IRC-SP041 junction concepts.

Table 9. Proposed for 2041 Mass Rapid Transit Network (Metro/ Lite Metro/ LRT/ Monorail/ BRT)

Project Type	Line Details	Recommended Phases	Length (in KM)	Max PPHPD (on any section)
Proposed lines	Patli Rly Stn-Delhi Commuter Rail (Can be started from Sarai Rohilla Rly Stn)	Phase - 2	24.7 (within study area)	6432
	Delhi-Gurgaon-Alwar RRTS Line (Within Gurugram)	Phase – 2	34.65	21841
	Vatika Chowk–Kherki Daula–Global City Badi Sati Chowk - Manesar – Panchgaon	Phase – 3	31.07	22385
	HUDA City Center – Subhas chowk – Hero Honda Chowk – Sector 10 – Sector 5 Chowk – Sector 22A – Cyber Hub (along with Spur line from Sector 9 to sector 101)	Phase – 3	25.36	25421
	Rezangal chowk– Dwarka Expressway – Dwarka Sector 21	Phase - 3	6.80	15391
	Faridabad – Ghata Village – Vatika Chowk (within Gurugram)	Phase – 3	9.6	12840
	Bhondsi village – Subhas Chowk – Rajeev Chowk – Sohna Chowk – Railway station	Phase - 3	17.09	23060
	Golf course extension road to sector 5 (Via HUDA city center metro stations)	Phase – 4	13.6	15153
	Kherki Duala to Sector 111	Phase – 4	16.57	7611
	Manesar (NH-48) - Pataudi Road to New colony more	Phase – 4	19.11	19328

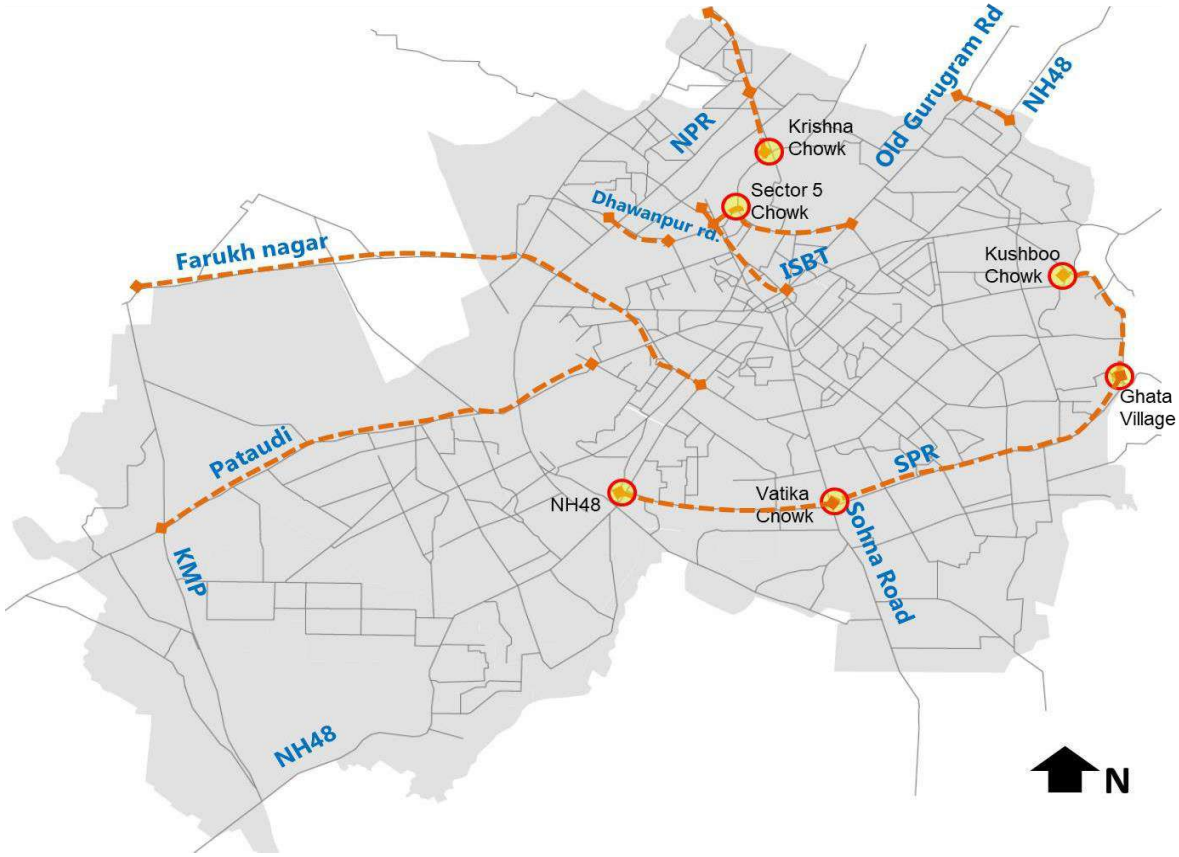

Figure 12 *Proposed Road widening links*

Traffic volume, turning motions, population, and employment surveys inform long-term and medium-term road network improvements. "BAU Scenario" Travel Demand Model included 2041 TAZ projections and external matrices. Lower V/C links were addressed by Greenfield development roads, reducing NH48 congestion. Sector linkages, Dwarka Expressway links, and outer ring roads are proposed. By 2041, the outer ring road will carry 8,000 peak-hour Passenger Car Units (pcu) via numerous development zones. Especially for Aravalli Biodiversity Park, the DPR must address environmental concerns (Sharma, 2018). The Greater Southern Peripheral Road will finish the outer ring road (GSPR). Network development is circular and radial. To meet future demand and urban expansion, road widening projects target sections, chowks, and critical crossroads.

5. DISCUSSION & CONCLUSION

In conclusion, this study highlights the critical importance of managing traffic congestion in Gurugram, Haryana, India, as a key factor of both economic vitality and ecological balance. The study's comprehensive assessment of this phenomenon's varied effects finds that traffic congestion exerts significant pressure on local productivity, commercial expansion, and air quality. Increasing urbanization and economic development, which have contributed to the increase in automobile traffic, demand an immediate reevaluation of transportation infrastructure and laws.

This study's in-depth examination shows the complex relationship between traffic congestion, economic vitality, and ecological equilibrium. The significant and diversified effects, which include economic output, commercial expansion, and environmental health, demand extensive intervention techniques. This study provides an invaluable resource for urban planners, policymakers, and stakeholders attempting to steer Gurugram towards a sustainable and efficient transportation paradigm by elucidating the negative effects on productivity, business expansion, and air quality, while simultaneously proposing viable mitigation avenues.

Considering the numerous obstacles faced by traffic congestion, this study emphasizes the necessity of coordinated actions among various parties. Governmental entities, urban planners, transportation professionals, and the public must work together to effectively implement the proposed mitigation strategies. The complex web of concerns necessitates a diversified approach that prioritizes eco-friendly means of travel, sustainable transportation management, and creative infrastructure solutions.

In conclusion, the complete analysis offered in this study serves as a clarion cry for collaborative initiatives aimed at alleviating Gurugram's traffic congestion. The profound effects on economic dynamics and environmental health need a paradigm change toward a more sustainable and efficient transportation architecture. Informed by thorough study and data analysis, the recommended techniques have the possibility of not only reducing traffic congestion but also building a prosperous urban environment while preserving ecological balance. This report provides a crucial road map for achieving a future in which Gurugram's transportation system is a model of efficiency, accessibility, and environmental responsibility.

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