

Analysis of integrated transportation system of Gurugram: A case of Bus and Metro transits

Himanshu,

Ph.D Scholar, Department of Civil Engineering, UIET, MDU Rohtak
Himanshu.Dangi@gmail.Com

Dr. Deepak Kumar

Assistant Professor, Department of Civil Engineering, UIET, MDU Rohtak

Abstract

Rapid urbanization in Gurugram, India, has led to traffic congestion, poor service, and increased pollution in the city's transportation system. Commuters increasingly rely on private and intermediate forms of transportation due to the need for more public transit. Visum, a macrosimulation program, was used to construct a four-stage sequential public transport model in Gurugram. The model was developed with the use of 1124 survey results. After the travel demand model was made, it was used to estimate the number of trips people and groups took in the baseline year using public and private modes of transportation. The results were verified using empirical evidence. To promote environmentally friendly transportation, the Gurugram metro was integrated with feeder modes and park-and-ride lots. The advantages of this were examined at the network level. After implementing multi-modal integration, metro rail usage increased. The long-term goal of this work is to get people out of their vehicles and onto public transit.

Key Words: Integrated Transportation System, Metro Services, Feeder Services, Parking and Ride facilities and Visum Software

Introduction

As India's population and cities expand, so do the complexities of the country's transportation issues. Congestion is a common problem in growing cities due to the presence of several competing modes of transportation. Gurugram experiences transportation-related problems due to the city's fast growth, including traffic congestion, subpar service, poor air quality, and unequal distribution of transit alternatives. Commuters are increasingly using private vehicles or paratransit, a service that supplements bigger transportation networks by offering individualized trips over short distances without established routes or timetables, while public transit systems struggle to keep up with the expanding demand for travel (Orski, 1975; Verma & Dhingra, 2005). As a result, we must

find and implement permanent solutions to the transportation problems that have been highlighted. Commuters in the city have benefited from several initiatives in recent years that have enhanced the city's public transportation system. As a result of rising demand from residents and workers, cities are investing in new transportation infrastructure.

The Gurugram Manesar Urban Complex (GMUC) ultimate development plan (2031) has several recommendations for improving the city's transit system and extending its public transit alternatives in the coming years. The master plan also highlighted the importance of establishing a comprehensive public transportation network to meet the growing population's needs and expand the range of travel options. The Haryana Mass Rapid Transport Corporation (HMRTC) commissioned DMRC to carry out a "Techno Feasibility Study" for the Mass Transit Corridor from "HUDA city center to Gurugram Train Station" to improve connectivity and mobility. So, in September 2016, DMRC handed in the Techno Feasibility report.

Another project HSIIDC is working on is extending the Metro line from HUDA City Centre (Gurugram) to Panchgaon. Thus, the track from HUDA City Centre to Subhash Chowk on Sohna road will be shared by the HUDA City Centre to Panchgaon Metro line of the HMRTC and the HUDA City Centre to Krishna Chowk Sector 22 - Cyber City Metro line of the HSIIDC. HMRTC has contracted RITES to draught the DPR for the HUDA City-Subhash Chowk-Krishna Chowk-Sector 22-Cyber City Metro Rail Link.

Over the past few decades, the continually increasing demand for public transportation in Gurugram has caused the city's public transportation facilities to become overburdened. Because of the particularly poor quality of the bus service, many people have been forced to look for alternative transportation methods such as automobiles and wheelchair vans, as they're aware that their productivity has suffered as a result.

By bringing together various modes of public transportation, service quality can be greatly improved (Ibrahim, 2003). These interconnected networks are designed to provide visitors with simple, convenient, secure, and low-cost transportation options (Luk & Olszewski, 2003; Ülengin et al., 2007). These infrastructures make it possible for different forms of transportation to work together rather than against one another. As a result, integrated transportation has been recognized as a way of taming the proliferation of private vehicle traffic on Gurugram's roadways.

A comprehensive Gurugram public transportation system was one of the key objectives of this study. In order to supplement the Gurugram metro rail system with additional modes and make up

for the absence of a last-mile connection, the current study investigated two multi-modal integration strategies, such as park-and-ride (P&R) amenities and linking the subterranean system to auxiliary modes. Travel needs for the base year 2013 were estimated using a four-stage model, which was subsequently confirmed using statistical data. The benefits to the system were then assessed after exploring the possible integration paths.

Study area and data collection

Existing transportation system in the city

The total number of cars in Gurugram's urban core has risen sharply in recent years. Around 58% of the population has a motorbike or scooter registration, compared to 41% who have a car registration. It has been noticed that approximately 28.2% of the road network has a ROW that is less than 10 metres, 28.7% of the road network has a ROW that is 10–20 metres, 17.8% of the road network has a ROW that is 20–30 metres, and 25.4% of the road network has ROW that is over 30 metres. It has also been noticed that around 20% of the road network and 28% of the road network, respectively, have carriageway widths that are less than or equal to 2 lanes. In comparison, approximately 26% of the roads have carriageway widths that are more than and equal to 6 lanes. The least amount of traffic has been seen in the portion between Basai Chowk and Gurugram, with just about 38,759 vehicles and 30,559 people-carrying units. The most traffic has been seen between Subhash Chowk and Rajiv Chowk, with approximately 1,21,403 vehicles and 1,07,242 PCUs. Currently, the most important terminal for intercity buses is the Gurugram Bus Terminal. This terminal serves 18,555 people daily and 2024 passengers during peak hours. There is a train station in Gurugram, located on the route between Gurugram and Jaipur. It is one of the primary stations that serve the area of Gurugram, which includes Gurugram itself and other portions of the Gurugram district. The Indira Gandhi International Airport, located near New Gurugram and can be reached through National Highway 48, is another amenity that the city of Gurugram offers its residents. This airport is situated 18 kilometers away from the center of Gurugram.

Travel characteristics and demand estimates

The research considered 145 different internal zones within GMUC and 4 external zones. Table 1 shows the predicted population and employment levels for 2021, 2025, 2031, and 2041.

TABLE 1: Land Use Parameters

Year	Population	Employment	WFPR (%)
2018	2104443	802518	38.13
2021	2361077	902591	38.23
2025	2973725	1190414	40.03
2031	4887500	2005440	41.03
2041	5836250	2462012	42.18

Source: Author’s calculations from GMUC Annual reports 2021 and 2022

For transport demand forecasting, a four-stage trip demand model has been devised. The average number of passengers using the study corridor daily is projected to be 5.34 million in 2025, 7.26 million in 2031, and 8.81 million in 2041.

TABLE 2: Peak hour peak direction trips in Gurugram metro corridors

Corridor details	Maximum PHPDT			
	2021	2025	2031	2041
HUDA City Centre to Subhash Chowk to Sector 22 to Cyber City to Sector 56	16485	19698	27341	33997

Source: Author’s calculations from GMUC Annual reports 2021 and 2022

Table 2 displays the highest peak hour peak direction trips (PHPDT). In view of the present economic crisis, the private sector's very ambitious aims will be limited to the master plan and recently approved plans, with a population of 48 lakhs in 2031. Around 15% of the SEZs are predicted to materialise, with momentum increasing after 2031. The Development plan's scope of work has been considered while projecting future growth. Table 3 shows the predicted population and employment.

Table 3 GMUC Projected Population and Employment under ‘Realistic Scenario’

Year	Expected Population	Expected Employment	Expected population SEZs	Expected Employment SEZs	Total Population	Total Employment
2011**	1708109	786829			1708109	786829
2018**	2104443	802518			2104443	802518

2021**	2240360	1024229			2240360	1024229
2025**	2973725	1190414			2973725	1190414
2031**	4080621	1401985	231870	447688	4312490	1849673

Source: Author's calculations from Development plan 2021 of GMUC

*Note: *census, **Analysis*

For the base year of 2008, the population was approximated by dividing the total number of household electrical connections (from the Haryana Electricity Department's GMUC region) by the typical number of households (from independently collected data). Water Supply Department estimates that there will be 37 lakh people living in the GMUC by the year 2031. By 2021 and 2031, disruptive investments will account for 15 per cent (in GMUC and the surrounding area). The rate of progress and the extent to which infrastructure is fully utilised will quicken after 2031. Using projections from the Development Plan, we may gauge future job prospects in the commercial and industrial sectors. Fifty per cent of population and employment growth occurs within GMUC, while the remaining fifteen per cent of nearby, soon-to-be-established SEZs are assessed on a phased basis. In addition, 20% of SEZs' land will be set aside for homes, and a density of 200 people per hectare will be mandated for the residential zone.

When it comes to meeting the transportation needs of the city's massive population, Gurugram's public transit options are invaluable. Buses and metro trains are the area's primary public transportation modes. Gurugram's metro system is quickly becoming vital to the city's transportation network. In addition to the metro, buses remain an important part of Gurugram's public transportation system. Paratransit modes, such as auto-rickshaws and cycle rickshaws, are useful for transporting people over shorter distances. Yet, Gurugram has seen a remarkable rise in vehicles and pedestrians using its roads over the past two decades.

Urban land use structure

Master Plan 2031 for the Gurugram Manesar urban complex

In the past 10 to fifteen years, Gurugram has grown and emerged as a commercial hub, attracting people from around Haryana. As a result, the villages surrounding the Gurugram Manesar Urban Complex (GMUC) grew rapidly and became satellite towns of Gurugram. The projected land use distribution indicates a strong focus on residential development and a continuation of the focus on industrial growth that has successfully boosted the local economy. There is still a large portion of the city dedicated to transportation. Table 1.3 and Figure 1.2 separately describe the preferred

configuration for future development and the existing landscape.

Table 4: Proposed Land Use of Gurugram Manesar Urban Complex Area

S. No.	Land Use	Area (Hectares)	Percentage (%)
1	Residential	16021	47.3
2	Industrial cum Commercial	6229	18.39
3	Transport and Communication	4428	13.07
4	Open spaces	2928	8.64
5	Public and Semi-Public Utility Area	2635	7.77
6	Other Area	1631	4.83
	Grand Total	33872	100

Source: Author's calculations from Town & Country Planning Department, Haryana



Figure 1. Gurugram's road network and traffic analysis zones (Study Area Zoning Map)

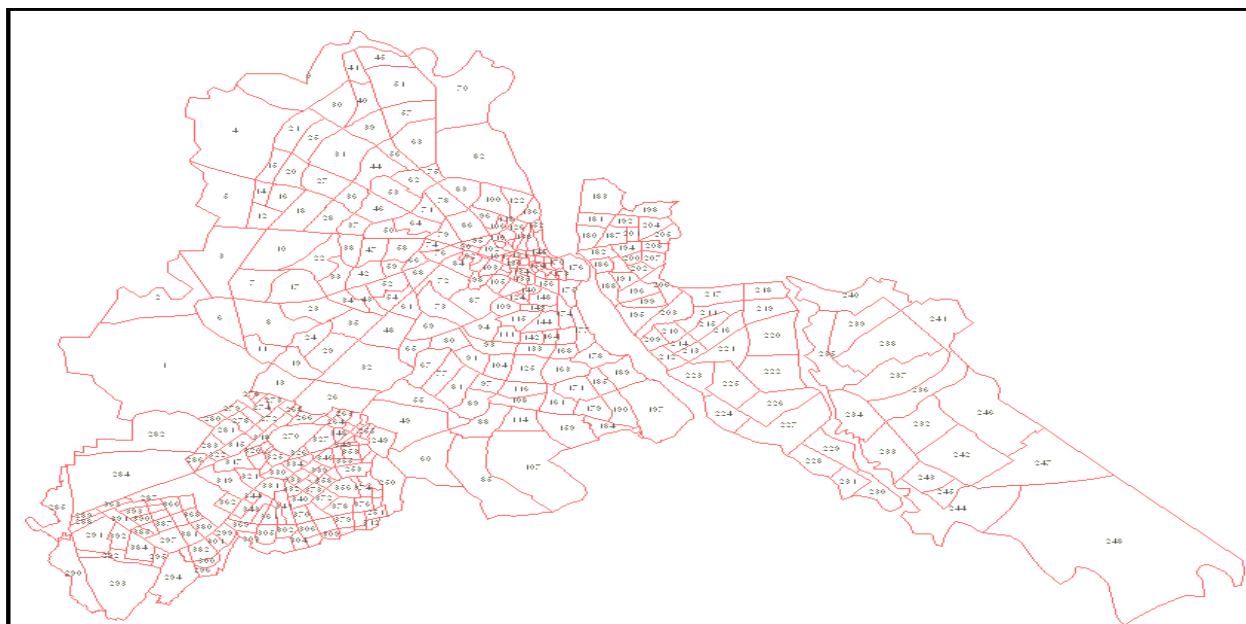


Figure 2 Study Area Zoning Map

Source: Author's calculations from Town & Country Planning Department, Haryana

From Sector 56 through Sikanderpur to DLF Phase 2 and DLF Phase 3 in Gurugram, the 11.7-kilometre-long Metro Rail (Rapid Metro) system is elevated the entire way. Rapid Metro has been running since 2013. The corridor is used by trains that are three cars in length. Stations, a depot, and other infrastructure have all been designed to accommodate a three-car train. Gurugram's projected metro rail line will connect with Rapid Metro, according to the plan. As a result of this connection, the Rapid Metro System's already-existing infrastructure can be used to its full potential. With the rapid metro system being integrated, the two systems must be fully compatible. As a result, the proposed corridors must adopt system standards analogous to those of rapid Metro.

2.2 Travel data collection

We used a standard survey instrument to gather information about your recent travels. In October 2022, researchers in Gurugram polled hundreds of residents to collect data about the city's tourism industry. Blocks or colonies were identified as clusters in the first step of sampling, while homes were located in the second. The data was acquired from individuals through one-on-one interviews to reduce the possibility of bias. After collecting the raw data, we cleaned it up by removing duplicates and those with missing information. In the end, we only considered 1124 of the initial responses after thinning the data. Table 1 shows the breakdown of the travel survey's four

components (home/personal/trip/vehicle). The socioeconomic features of travelers were characterized by their residences and personal information.

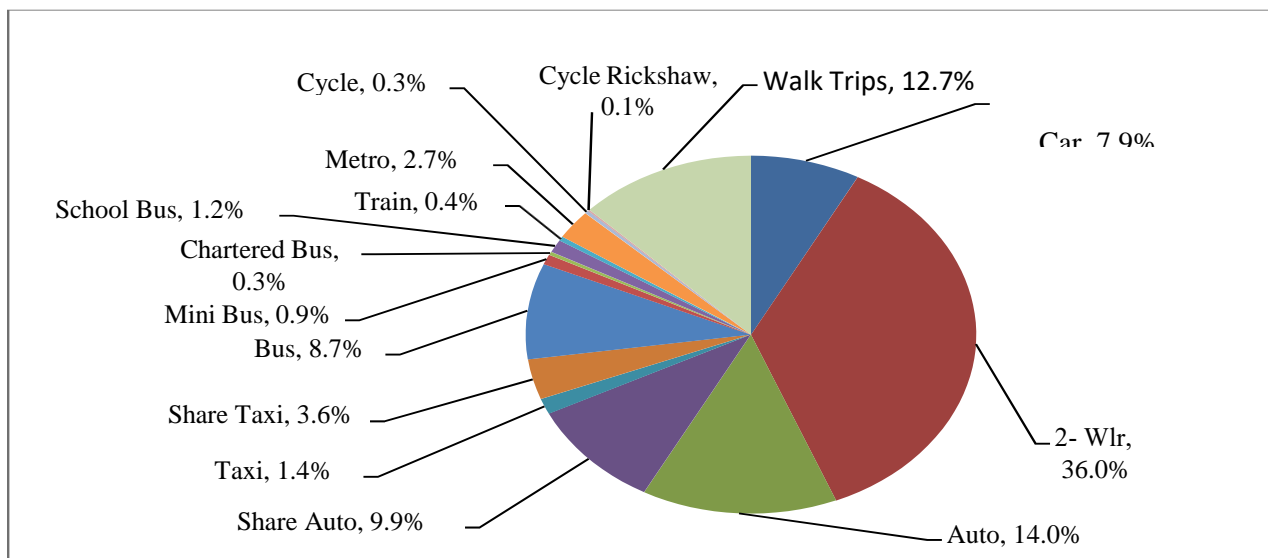
Table 5. Parameters considered for household survey

Information category	Details
Household information	Household size, income, number of workers, number of literates and so on
Personal information	Age, gender, qualifications, occupation and so on
Trip information	Origin–destination data, start and end time, access and egress time, frequency of trips, preferred mode of trip, cost of travel and so on
Vehicle information	Vehicle ownership, types of vehicles

Source: Author’s calculations from Town & Country Planning Department, Haryana

Travel Behaviour Characteristics

The home travel behaviour data showed that most commuters were between 25 and 55. About 45% of commuters in this age range opted to drive themselves to work, while 36% rode motorcycles, and 9% took the bus. Of all homes, those making between 35000 and 50000 Indian Rupees (INR) per month constituted the largest share (28%) of all income levels. According to the data, two-wheeled vehicles, bicycles, and walking were the most common modes of transportation for



households with monthly incomes of less than 35000 INR.

Figure 4: Distribution of daily passenger trips by mode (including walk)

Source: Author’s calculations from GMUC Annual reports 2021 and 2022

The data also showed that the vast majority (79%) of trips were made for work-related reasons. While just 16% of all families reported having no cars, the proportion of households with only one

car was much higher at 59%. (Figure 3). We found that 38% of all journeys were made in automobiles. In comparison, 36% of trips were made using two-wheeled transportation, 8% via cars, 10% via buses, 13% via the subway, 5% via auto-rickshaws, 19% via bicycles, and 13% via foot. This is demonstrated in Figure 4.

4. Building a Model of Traveler Demand Predicting how individuals would choose to travel in light of the average costs associated with various routes is a crucial part of travel demand modelling (McNally, 2007). Visum (PTV, 2011) is a macroscopic computational model used to create a four-stage model of the Gurugram road network, which considers trip formation, trip dispersion, adaptive control, and traffic allocation. Visum, the transportation planning and macrosimulation software, allows for four-stage traffic modelling (Häll, 2006). A robust GIS-enabled tool may be used for public and private traffic forecasting and analysis. The volume calculation in this study involved the development of numerous mathematical models and approaches, one of which was the now-standard four-stage trip generation model. The road network and trip attributes were employed as primary data points in the model's development. Secondary network data was digitized using the ArcGIS system. This referred to roadways (including interchanges) and garages (Esri, 2011; Google Corporation, 2013). The following sections provide a comprehensive breakdown of the four-step trip planning process.

Table 6 Composition of Traffic plying on Outer Cordon points (24 Hrs)

Sl. No.	Location on	Vehicles				%age of Vehicles			
		SMVs	G-V	P-V	Total	SMVs	G-V	P-V	Total
1	NH8 TowardsDelhi	1143	11821	112286	125250	0.91	9.44	89.65	100
2	MG Road	1547	2689	78784	83020	1.86	3.24	94.90	100
3	Faridabad Road	185	1961	11328	13473	1.37	14.55	84.07	100
4	Sohna Road	352	4798	12588	17738	1.98	27.05	70.97	100
5	NH8 TowardsRewari	143	12753	25701	38597	0.37	33.04	66.59	100
6	Pataudi Road	488	4107	12227	16821	2.9	24.41	72.69	100
7	Basai Road	51	279	873	1203	4.21	23.23	72.56	100
8	Daulathabad Road	158	2018	3558	5734	2.75	35.2	62.05	100
9	Najafgarh Road	558	148	3075	3781	14.75	3.92	81.33	100
10	Old Gurgaon Road	3618	5365	38721	47703	7.58	11.25	81.17	100
Total		260120	45939	299140	260120	2.33	13	84.67	100

Source: Author's calculations from GMUC Annual reports 2021 and 2022 (SMVs= Slow Moving Vehicles, G-V= Goods Vehicles, P-V= Passenger Vehicles)

Table 6 shows the types of traffic that pass via the perimeter checkpoints. Most traffic in all areas comprises passenger cars, with shares ranging from more than 65% on NH8 heading toward Rewari to around 95% on MG road. Many trucks and buses travel the NH8, Old Gurgaon Road, Sohna Road, etc. The percentage of goods-carrying automobiles ranges from 3 per cent to 35 percent. Around 40,000 commercial/goods trucks enter and leave the study region daily.

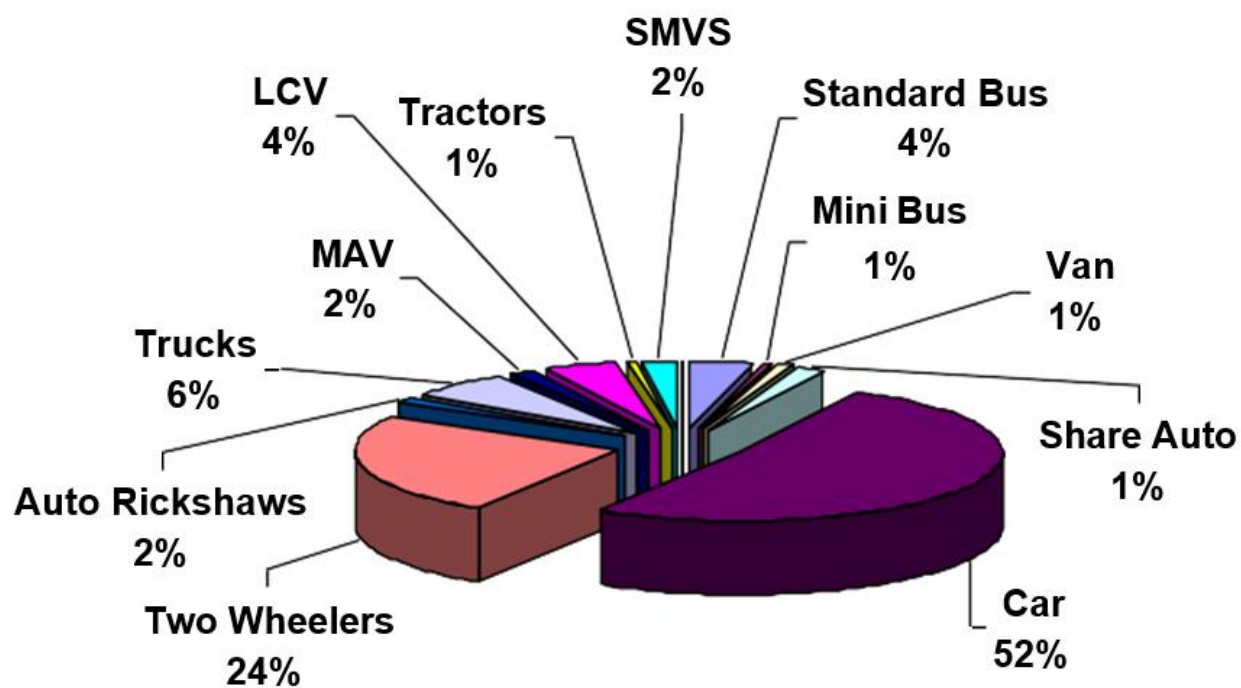


Figure 5: Number of Vehicles going across Cordon Points per day

Trip Length

Figure 5 displays the typical make-up of vehicles that pass through outer cordon checkpoints. There are mostly cars, then motorcycles, trucks, and buses. The average distance walked on foot is 4.06 kilometers, as shown in Figure 6. The average distance travelled by cars is 14.39 kilometers, by motorcycles 11.76 kilometers, and by shared automobiles 9.89 kilometers. The maximum average trip travelled by people is through metro routes, which accounts 15.01 kilometers followed by cars, chartered buses and two wheelers. Whereas people travel minimum by cycle, rickshaws or walking too and when it comes auto or taxi then people travel around 7km per vehicle.

Trip generation

The trip creation process correlates the number of trips generated from a particular set of influencing factors of zones with the number of trips drawn to those zones. In trip generation modelling, a region's origins and destinations serve as dependent variables. Population size, household density, labor force participation, literacy rates, and median household income were all considered potential explanations in this analysis. There were correlations between each independent variable and the total number of trips. Thus, it became evident that the various factors in the model affected the trip options. To use a series of multivariate linear regression studies, we identified the functional relationships between each trip type and its affecting characteristics. The model of trip creation used in this investigation's functional relation is shown in Equation 1.

Equation 1: $Y = a_0 + a_1X_1 + a_2X_2 + a_3X_3 + a_4X_4 + a_5X_5$ -----

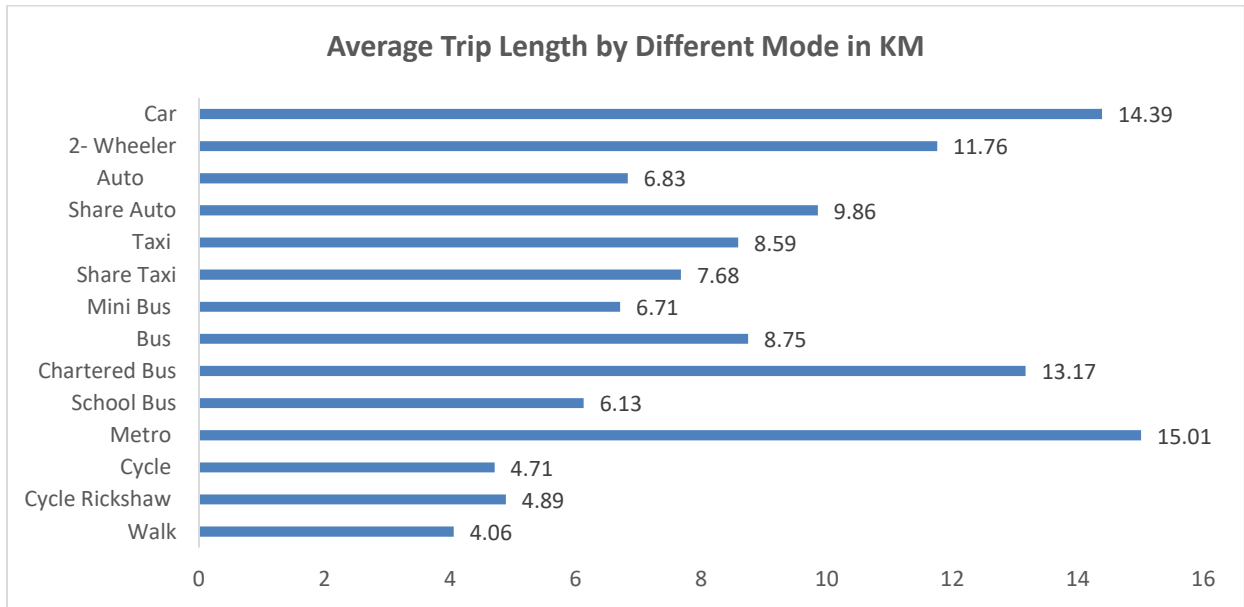


Figure 6: Distribution of average trip length by mode

Population (X_1), housing stock (X_2), literacy rate (X_3), the labour force (X_4), disposable income per household (X_5), and model coefficients (a_0, a_1, \dots, a_k) are the independent variables. The Y-value represents the total number of journeys beginning or ending in that area. We developed productivity and attraction trip-generating equations to estimate R^2 values for different modes and trip purposes (such as working from home and attending school). According to the R^2 values (0.95), the generated trip generation model can accurately forecast future trips upto 95% of the time.

Trip distribution

Visum's trip distribution depends on the "Gravity" model, which is now the most popular way to plan trips. To make the variables required for the skim matrices, the quickest paths between each OD pair (i.e., between the origin and the target) were found. Distance, trip time, and cost are the three things that are used to determine the "deterrent function," which is also called the "characteristic for geographic isolation," between the starting point and the end point.

Equation 2: $F(U_{ij}) = a \times U_{ij}^b \times e^{(c \times U_{ij})}$

U_{ij} represents the total time and money required to go from zone i to zone j , and Visum is used to calculate calibration parameters a , b , and c . After analyzing the trips, Visum came up with the coefficients $a = 0.705$, $b = 0.005$, and $c = 0.099$. This Gravity model calibration data allowed for calculating OD matrices for non-local journeys, which were then employed in further iterations of the trip generation model. Chi-square testing was used to verify the reliability of the anticipated journey distance. Using both actual and predicted trip frequencies, we calculated a chi-squared value of 2789. At the 1% significance level, the chi-squared critical value is 3028. Based on these results, we can infer that the discrepancy between the actual and predicted travel times was negligible.

Mode choice

The preferences of commuters in selecting a mode of transportation are crucial in shaping public transportation policy. Analysis of commuting mode selection takes into account commuters' decision-making processes. A multinomial logit model assessed the mode split among the various transportation options. It is possible to read Equations 3 and 4 as encapsulating the logit model. A model's utility, or U_i , is defined as

Equation 3: $P(i) = \frac{e^{U_i}}{\sum_{j=1}^l e^{U_j}}$

(In equation 3, the assigned values are represented as U_i is the worth of mode j , $P(i)$ is the probability that mode and i is the total number of modes)

In order to accomplish this, we make use of the following notation: (a_n, b_k, X_n, V) , in which

a_n refers to a constant that is unique to mode I , b_k refers to a parameter that is unique to mode k , X^n refers to a model variable that is unique to mode k . V refers to the maximum number of model parameters.

$$\text{Equation 4: } U(i) = a_n + \sum_{k=1}^V b_k \times X_k^n$$

Eight different types of transportation were tracked and analysed for this investigation. They included individual vehicle travel, carpooling, motorcycles, bicycles, motorized tricycles, buses, subways, and foot travel. Visum's mode choice model creation is more labor-intensive since it necessitates a separate demand stratum for each type of transportation in a skim matrix. The models that were generated by the Limdep econometric program N-logit and for which the essential mode-wise utility parameters were acquired are based on version 5 of Visum. This was done in order to circumvent the issue (Greene, 2012).

There were a total of 1124 samples from different households. The investigation showed that the two most important factors in choosing a mode of transportation are IVTT (time spent travelling in a vehicle) and travel cost. Estimates for the modal shares of various transportation options were as follows: 37.10% for motorcycles, 29.20% through autos and shared taxis, 8.3% by buses, 8.2% for buses, and 3.9% for the metro. These insights on mode-specific travel composition aided in creating OD matrices for various modes. It has been found that people have reduced their walking trips, auto trips and traveling via buses and preferred Metro services, two wheelers and cars. Finally, these OD matrices were implemented into the traffic distribution scheme.

Traffic assignment

The OD trip matrices produced as a result of the modal split procedure were used in constructing a Visum traffic assignment model. The user equilibrium strategy was analysed for its potential application in assigning private transportation services. The public transportation modes were assigned on an all-or-nothing basis so that riders could choose the fastest available route within the system, regardless of how the lines connect or when they run. For the base year, traffic assignments were made in Visum, and the daily vehicle and passenger volumes on each road connection were then calculated as the output (Figure 6).

The timetable-based assignment was used for the Metro, so rides start and end at predetermined times. Macrosimulation was performed using collected metro line arrival, departure, run, and stop schedules (DMRC, 2015) fed into Visum. Schedule-based assignments for metro ridership in terms of passengers/day are depicted in Figure 6. At the network level, it was determined that there were around one lac daily metro riders and that the average metro traveler speed was 32.5 kilometers per hour.

Assessment of integrated transportation networks

Passengers benefit from a greater standard of service and financial savings through an integrated multi-modal system (Fierek & Zak, 2012). Here, we will go over how we put the plan into action and what we learned from analysing the results. Here are some of the possible outcomes of the current research may be like current transportation infrastructure where Feeder mode incorporated into the metro system or gainful employment with passenger and roadside assistance. For this purpose, in Visum, a four-stage transport model was developed, validated, and evaluated before being put to use in the analysis and comparison of three different network-level scenarios.

Integration of a feeder mode with the metro

In recent years, especially in less developed countries, paratransit has become more important to connect to public transit (Tangphaisankun et al., 2010).

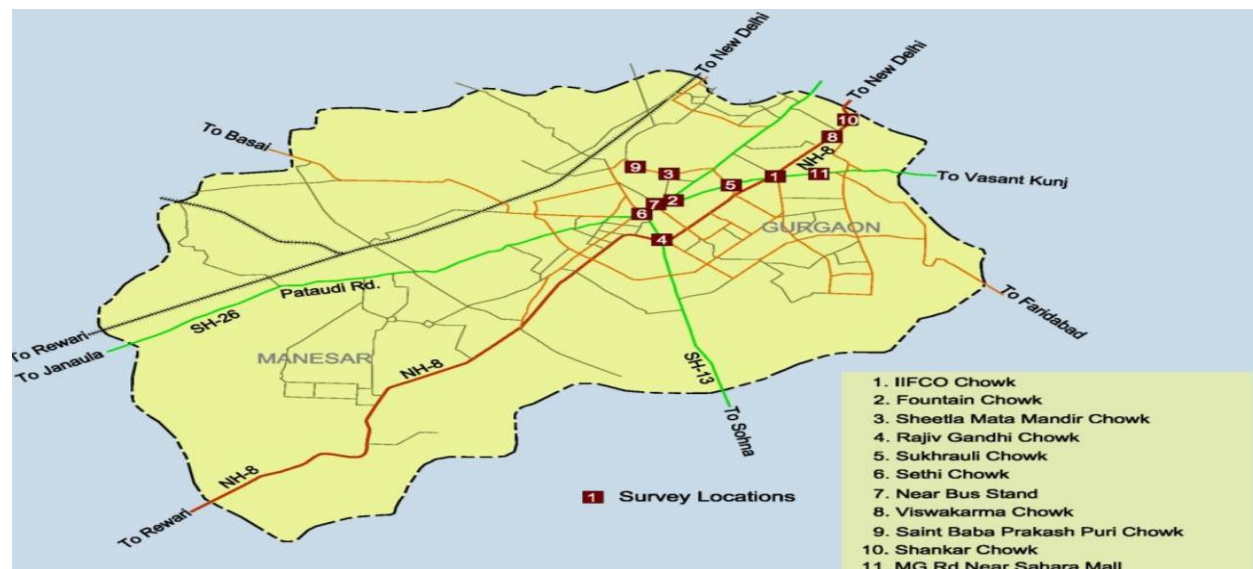


Figure 7 Metro Key stations

Services like this are crucial to metro systems like Gurugram's success. Gurugram's feeder modes serve as entry and exit points, easing the city's public transportation system's last-mile connection problems (Gupta & Agarwal, 2008). Attempts were made in the present investigation to provide a mix of metro and feeder modes to facilitate integration. For instance, feeder mode may be a metro or bus going to and from a specific station. The combined metro and feeder system is thus the ninth mode option considered. Based on this strategy, we assumed that Feeder transit options are available within a 500-meter range of the metro station.

The maximum distance that feeder services will travel to reach a metro station is six kilometers. The area within a radius of six kilometers of a metro station is the only one with any available connectivity alternatives. The input components IVTT and OVTT, in addition to the cost of using the metro, were combined into the mode option so that a new one could be generated. The efficiency coefficients were utilized in a sensitivity study that included an additional feeder mode. We also considered that the OVTT (access and egress times) should be reduced due to the improved link, while the IVTT (journey time) will increase if a customer takes both the subway and the feeder on the same journey. It is anticipated that the overall trip cost will go up as a direct consequence of adding another mode of transportation and the rise in IVTT.

According to the findings, in comparison to the scenario that served as the baseline, the IVTT would increase by 15%, which is equivalent to a quarter of the total trip time; the OVTT would diminish by 15%, which is equivalent to a quarter of the total trip expense; and the cost would increase by 10%, which accounts for one-third of the total cost of the trip. The modal split after the feeder mode was introduced is depicted in Figure 8. In scenario 1, the number of commuters who use the metro rises from 2.7% to the current case of 3.9%. If a feeder link were created, 1.2% of current riders would transfer to the metro. In the following section, the study will examine the connected metro system using a feeder mode in greater depth, evaluating the system at the network level and comparing the system to a larger, more general scenario.

Network-level evaluation of metro integration with feeder mode to compare the cases in detail. Table 7 is an analysis of how the addition of a feeder mode would affect the Metro's ridership. Overall, increased ridership on the metro system brought the total number of riders to 103385 in 2022, up from 63268 in 2018. If more people started taking the underground, the proportion of

people using the most popular privately-owned vehicles would drop significantly. As a result of the combination of the Metro with a feeder mode, the total number of private mode journeys taken on the network was reduced by 2.60% whereas journey through two wheelers and cars have been increased by 1.10% and 0.4% respectively. As shown in Table 7, these modal shifts also increase average travel times for passengers. The average speed of phase 1 riders increased from 32.8 to 35.2 kilometers per hour. The corresponding increase on the phase 2 was from 32.5 to 34.7 kilometers per hour.

Incorporation of Park and Ride Facilities and Metro Services

In this section, the purpose of the study is to examine how installing P&R facilities in certain areas of Gurugram may increase metro ridership. P&R schemes (Park and Ride) are parking lots for cars, bikes, and bicycles connected to public transit (buses, subways, and commuter trains) so that drivers can leave their cars and continue their commute on public transportation. Travelers from the city's outskirts now have an easier time getting to their destinations thanks to the availability of P&R areas. Commuters can also benefit from P&R sites since they save time and money by allowing them to forego the hassle of travelling through heavy traffic and finding parking in the city's pricey core (Manns, 2010). Consequently, they contribute to reducing congestion on urban streets by encouraging and making it easier for people to use mass transit. Because of this, P&R schemes can considerably impact travel patterns, and therefore, they need to be accounted for in-demand models (Szarata, 2005). In order to model a P&R system, they employed Visum. Visum should add P&R as a new mode.

- Telling Visum where park and ride locations are.
- Breaking up P&R trips into legs for personal and community transportation to determine the (non-)usefulness of the P&R (park and ride) mode.

The P&R approach was widely adopted across all demand levels (home-based work, education and other activities). Parking fees for P&R journeys were factored into calculating its disutility at varying decrements to reflect travel costs accurately. Because of this, we could better predict how much people would switch modes as parking fees were reduced. Disutility must be determined when a P&R mode is added to the mode selection procedure. Assuming an OD connection,

Table 7. Comparative analysis of metro ridership with and without feeder mode and Parking services

Travelling Route via Metro	Base Case			With Feeder Mode		
	Passenger-h	Passenger-km	Average passenger speed: km/h	Passenger-h	Passenger-km	Average Passenger Speed: km/h
Phase 1	35684	1170435	32.8	65298	2298490	35.2
Phase 2	27584	896480	32.5	38087	1321619	34.7
Travelling Route via Metro	Base case			With park and ride mode (P & R) Average Parking Cost Per Trip Rs 15		
	Passenger-H	Passenger-Km	Average Passenger Speed: Km/H	Passenger-H	Passenger-Km	Average Passenger Speed: Km/H
Both Metro Routes	63268	2062537	32.6	116985	4106174	35.1

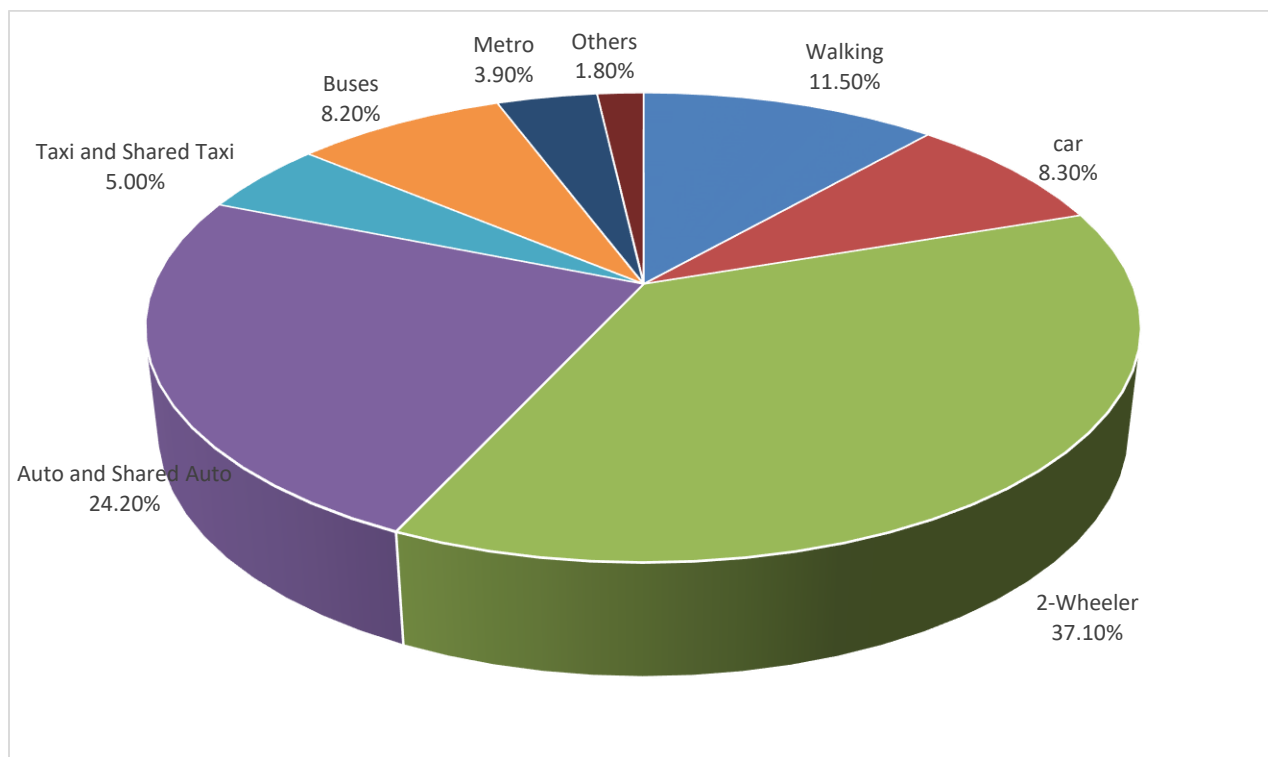


Figure 8 Modal split after incorporating feeder services

The total price considers both the amount of time spent going to and from the P&R site and the money spent on using public transportation once you are there. During the survey, it was decided

to use a per-mile average of Rs 15 on an average to account for the different expenditures associated with company vehicles and personal vehicles. Each of Gurugram's metro stations has its own parking lot, where motorcyclists, scooter riders, and vehicle owners can store their transportation while they use the metro services. Prices may be adjusted for other private modes of transportation. The parking cost ranges from 10 to 50 Indian Rupees (INR) for stays of between six to 24 hours, depending on the length of the stay. This was considered while calculating the possible influence on passengers' mode shifts that could result from a reduction in parking costs from 10% to 5% for the same periods.

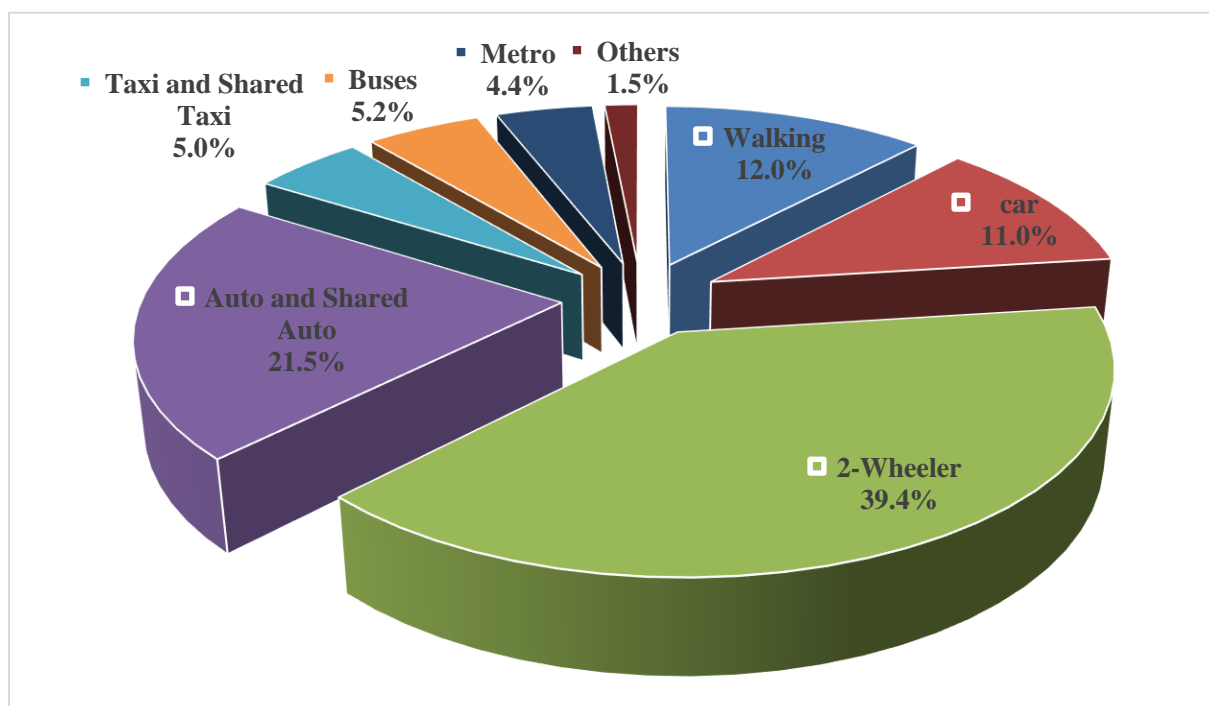


Figure 9: Modal split after incorporating Parking services

When parking prices were kept around Rs 15 per trip to the customers, they are more likely to avail the metro services and when the parking cost tends to be around Rs 50 or more then they prefer to travel through their vehicle than metro. Only people travelling to Delhi or for more than 10KM from their destination source, show their willingness to use metro services, hence creating the positive impact of Parking services on the metro rides. On the other hand, for travelling less than 10KM per trip, they prefer to go vis their own conveyance than metro. Parking services has witnessed 2.6% overall increase in model split of metro system as opposed to baseline position. This represents a 2.6 % increase when the entire metropolitan area is considered. As shown in

table 8, the percentage of people using the metro went from 2.7% to 4.4%, when the parking facilities are provided nearby metro stations. This shows people are ready to pay the charges if better facilities could be available to them to save their time and energy. As a result, if parking fees were reduced, more individuals would opt to use the underground services.

Visum could find the shortest path for each Origin-destination pair in the scenario by comparing all of the zone centers to the P&R sites. With the help of rating factors for both private and public transportation, the best P&R routes and the mode shift that goes with them were found. (IVTT, OVTT, and approaching penalties, i.e., parking fines). Table 7 shows that a lot more people are using the subway system.

Conclusion

The requirements of tourists from A to B can be broken down into four distinct phases, as explained by the Travel Demand Model. In order to reliably replicate urban environments and provide reliable projections of future traffic patterns, transport models were constructed for this study. The most important findings from evaluating the data from the home surveys were that most employees were between the ages of 31 and 50 and primarily utilized their automobiles for mobility. Sixty-one percent of homes said they only have one car, and 19 percent said they have none, suggesting that their members seldom drive and instead rely on other modes of transportation.

The main result of this study is a review of how to use the macrosimulation tool Visum to create and run transportation modeling and system integration. Setting up a set of settings is part of the process. The procedure takes into account creating a set of parameters.

It was also possible to use macrosimulation to make demand models for transportation networks that work well together. Knowing the benefits of an integrated transportation network can help you figure out how likely it is that people will switch from driving their own cars to taking the train when you compare the trip patterns of business and public modes. Two possible future integrated solution situations were also compared to the performance of the present transportation network. Our study shows that if feeder modes and P&R services were choices for mode choice, the metro share could witness tremendous increase as high as possible. A quantitative study of P&R choices showed that the best way to improve network access might be to charge minimum amount around Rs 10 or Rs 15, so that people should not feel that their trip has cost them more than if they could have travelled through their vehicle.

As a result, it can evaluate the worth of a linked network by considering the degree to which it facilitates travel. Theoretically, the strategy's objective is to entice passengers to switch from using private modes of transportation to public transit by offering the possibility of greater linkage to other transportation systems (the metro in this example study). In addition to underlining the necessity of demand and supply data and variables in projecting travel behavior and developing an effective transportation system, the following are the results of this study:

The use of the strategy should be anticipated to result in favorable consequences. Despite this, there is room for additional enhancement. This would make it easy to spot and avoid common errors when estimating the travel demand. To this purpose, increasing the size of the sample population and gathering data from various locations around the research area will help refine the model. Even though there were some holes in the data, the integral variables that were utilized in constructing the model adequately represented its characteristics and validity. In addition, additional research might be carried out to investigate the advantages of integrating transportation systems using macroscopic and microscopic modeling strategies.

The price of parking could be reduced to Rs 10 per hour to convince the travelers to use the metro services, which could result in improving metro shares and if P & R amenities were made available, representing a savings of 50 percent. When P&R was implemented at rates of 5 and 10 Indian Rupees per hour, the average speed of passengers increased from 27.86 kilometers per hour in the base case to 29.05 kilometers per hour.

References

- CSIR-CRRI (CSIR-Central Road Research Institute) (2016) 12th Five Year Plan Network Project on “Development and Application of Technologies for Sustainable Transportation” (SUSTRANS ESC-0106). CSIR-Central Road Research Institute, Delhi, India.
- Department of Town and Country Planning (DTCP), 2010, Government of Haryana, Integrated Mobility Plan for Gurgaon Manesar Urban Complex.
- DIMTS, Implementation of City Bus Service Project in Gurugram – Bus Route Planning and Rationalization, March 2018.
- DMRC (Delhi Metro Rail Corporation Limited) (2023) Journey Planner. DMRC, Delhi, India. See <http://www.delhimetrorail.com/metrofares.aspx> (accessed 05/03/2023).

- ESRI (Environmental Systems Research Institute) (2011) ArcMap 9.2. Esri, Redlands, CA, USA.
- Fierek S and Zak J (2012) Planning of an integrated urban transportation system based on macro-simulation and MCDM/A methods. *Procedia Social and Behavioral Sciences* 54: 567–579.
- GMDA (Gurugram Metropolitan Development Authority), 2019, Comprehensive Mobility Plan for GMDA Area, Transport Planning Department, School of Planning and Architecture, New Delhi.
- GNCTD (Government of NCT of Delhi) (2022) Economic Survey of Delhi 2021-22. Government of NCT of Delhi, India. See http://delhi.gov.in/wps/wcm/connect/DoIT_Planning/planning/economic+survey+of+delhi/economic+survey+of+delhi+2021+2022 (accessed 07/12/2022).
- Google Corporation (2022) Google Earth 7.1.2. National Capital Territory of Delhi (28°40'N, 77°14'E), Roads Data Layer.
- Google Corporation, Mountain View, CA, USA. See <http://earth.google.com> (accessed 02/01/2023).
- Greene WH (2012) *Econometric Analysis, NLOGIT Version 5, Reference Guide*, 5th edn. Prentice Hall, Plainview, NY, USA.
- Gupta S and Agarwal M (2008) Role of cycle rickshaws as a potential feeder mode to Delhi metro. Proceedings of the 23rd ARRB Conference ARRB08 Collaborate: Research – Partnering with Practitioners, Adelaide, Australia.
- Hall CH (2006) A Framework for Evaluation and Design of an Integrated Public Transport System. Doctoral thesis, Linköping University, Linköping, Sweden.
- Haryana Mass Rapid Transport Corporation Limited, 2019, Detailed Project Report for Metro Rail Connection from Huda City Centre – Subhash Chowk – Palam Vihar – Sector 22 – Cyber City, Gurugram.
- Ibrahim MF (2003) Improvements and integration of a public transport system: the case of Singapore. *Cities* 20(3): 205–216.
- Luk J and Olszewski P (2003) Integrated public transport in Singapore and Hong Kong. *Road and Transport Research* 12(4): 41–51.

- Manns J (2010) Park-and-ride – politics, policy, and planning. *Town and Country Planning* 79(3): 144–148.
- McNally MG (2007) The four-step model. In *Handbook of Transport Modelling*, 2nd edn (Hensher DA and Button KJ (eds)). Emerald Group Publishing Limited, Bingley, UK, pp. 35–53.
- Orski CK (1975) Paratransit: the coming of age of a transportation concept. *Transportation* 4(4): 329–334.
- PTV (Planung Transport Verkehr AG) (2011) *Visum 12 User Manual*. PTV, Karlsruhe, Germany.
- Ravi Sekhar Chalumuri, REJITHA Nath, Madhu Erampalli, (2017), Development and evaluation of an integrated transportation system: A case study of Delhi, *Proceedings of the Institution of Civil Engineers*. <https://doi.org/10.1680/jtran.16.00003>
- RGI (Registrar General of India) (2022) *Census of India 2011: Rural Urban Distribution of Population*. Registrar General of India, Delhi, India. See http://www.censusindia.gov.in/2011census/population_enumeration.html (accessed 05/12/2022).
- Szarata A (2005) Modelling of park and ride trips. *Proceedings of the 6th International Conference Environmental Engineering*, Vilnius, Lithuania, pp. 642–645.
- Tangphaisankun A, Okamura T, Nakamura F and Wang R (2010) A study in integrating paratransit as a feeder system into urban transportation and its effects on mode choice behavior: a study in Bangkok, Thailand. *Proceedings of the 12th WCTR Conference*, Lisbon, Portugal.
- Ulengin F, Onsel S, Topçu YI, Aktaş E and Kabak Ö (2007) An integrated transportation decision support system for transportation policy decisions: the case of Turkey. *Transportation Research Part A: Policy and Practice* 41(1): 80–97.
- Verma A and Dhingra S (2005) Feeder bus routes generation within integrated mass transit planning framework. *Journal of Transportation Engineering* 131(11): 822–834.