# EVALUATING THE LAST MILE CONNECTIVITY

# FOR

# GURUGRAM RAPID METRO

*A Thesis Submitted in Fulfillment of the Requirement for the Award of the Degree of*

**MASTER OF ENGINEERING**

**IN**

**INFRASTRUCTURE ENGINEERING**

*Submitted By*

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## DECLARATION

I hereby declare that this work which is being presented in the thesis entitled "Evaluating the Last Mile Connectivity for Gurugram Rapid Metro" in partial fulfilment of the requirement for the award of degree of Master of Engineering in the field of Civil Engineering with specialization in Infrastructure Engineering submitted at Thapar Institute of Engineering & Technology (Patiala) is an authentic record of my own work carried out during the period from 14.08.2018 to 14.08.2019 under the guidance of Dr. Mansha Swami, and Mrs. Neena Garg.

The matter embodied in this thesis has not submitted by me for the award of any other degree or diploma.

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This is to certify that the above declaration made by the student concerned is correct according to the best of my knowledge and belief.

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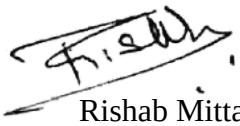

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# ABSTARCT

The prospect of providing valuable, economic and comfortable “Last Mile Connectivity” (LMC), i.e. from the trip ends to the point of accessing a public transport system, is an area which is not given proper attention in cities of India, which includes many metropolitan/millennium cities like Gurugram. Traffic in Gurugram has grown at an unsustainable pace and around 1 lakh vehicles being registered in the city every year, also the number of private vehicles had increased tremendously in Gurugram since 1991 to 2019. In this alarming situation, the Last mile connectivity (LMC) is of vital importance that a rapid transit pattern shift is taken on in order to move people away from private vehicles towards the role of public transit.

The research discusses about overview of transport conditions around Gurugram Rapid Metro corridor in the state of Haryana, India and by studying the inventory of area and doing surveys regarding commuter’s perception for last mile connectivity of Gurugram.

The important questions that the research tries to address is evaluation of the last mile connectivity with the help of Data Envelopment Analysis to analyze the efficiency of various attributes of Gurugram Rapid Metro Corridor i.e. The impact on interconnectivity convenience, travel time ratio & travel cost with the help of suitable inputs. Egress or last mile was identified as the weakest leg of the journey.

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# 1. INTRODUCTION

## 1.1 GENERAL

In Today's scenario, globalisation has boosted development of many cities and competition is still on and it has enormously raised the scale of economic, social, educational and technologically that the need to connect both in physical and virtual space has raised accordingly. Journey or travel thus takes centre stage of every individual; it gives utility to certain extent but with many negative impacts like congestion, pollution, accidents, global warming, physiological and other health hazards. With rapid urbanisation, population of India has put tremendous strains on urban transport system. Travel demands has highly triggered in millennium and metropolitan cities like **Gurugram**. Use of private vehicle is individual entity whereas public transport is public entity and public prefer to use public transport if they find good conveyance to reach it, that is the **"Last Mile Connectivity"**
Most Cities around the world are trying to curtail use of private vehicles and promote public transport, but the increased urbanisation has changed the life style and socio-economic conditions which is accompanied by increasing vehicle ownership, growing the share of private modes of travel, hence concerns are raised to improve the last mile transportation system such that proper utilisation of present public transport system could be done.

## 1.2 GLOBAL URBANISATION SCENARIO

The migration of rural population towards urban cities has accelerated in the past 40 years, particularly in under-developed regions, and the percentage share of the world's population living in urban areas has increased to 47 % (2.8 billion people) in 1999. Currently global urban population is growing by 60 million persons per year, which accounts to approximately 3 times the increase in the rural population. The number of people in developing countries residing in urban cities has almost doubled since 1960 (i.e. from 22% to more than 40%), while talking about more - developed locations the urban population share has grown from 61% to 76% (Fig: 1.1). This shows there is a significant link

between population migration from rural areas to urban areas and declines in average familylsize. (Source: United Nations Population Fund (UNFPA) (UNFPA, 2018)

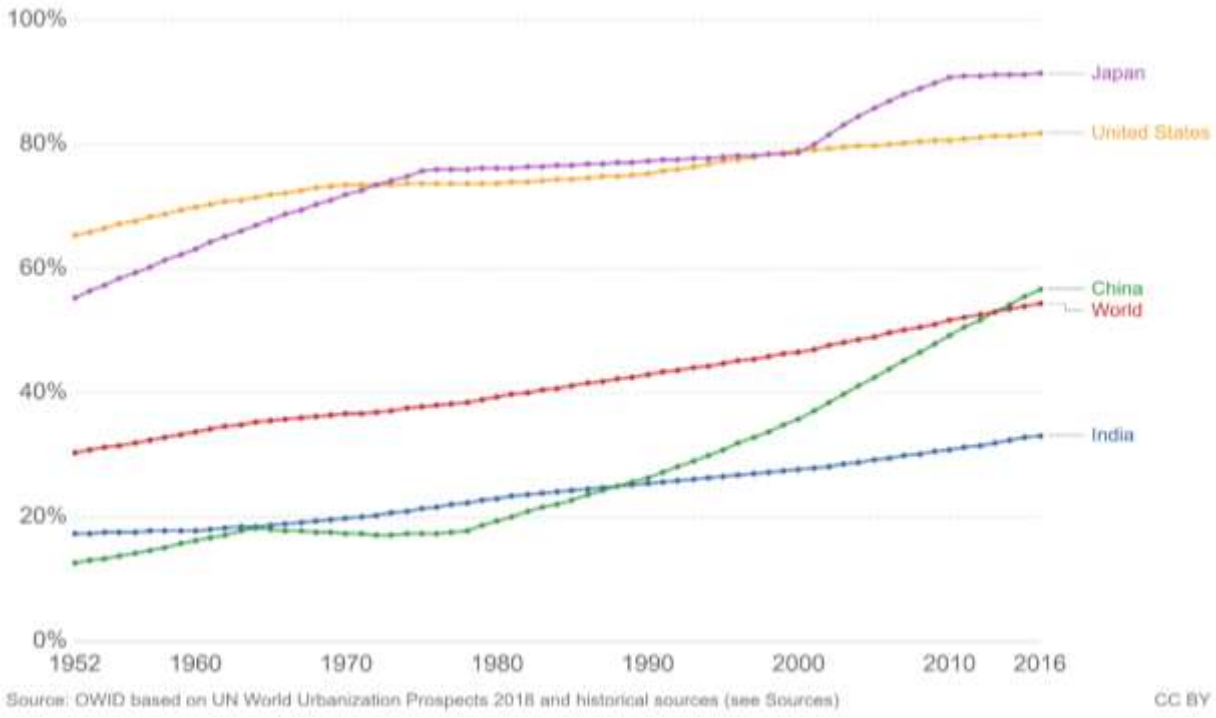



**Fig: 1.1 Global Population Trend over past 50 years**

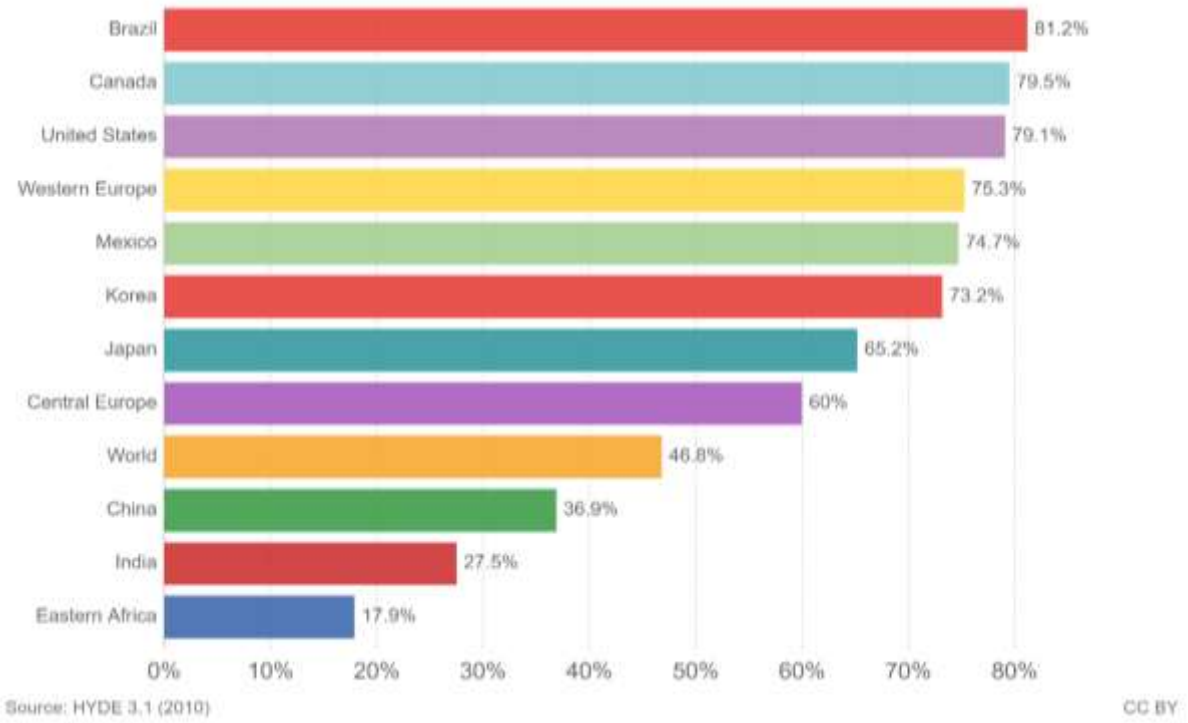



**Fig: 1.2 Global Population share for year 2000**

As explained in Fig: 1.2, Africa and Asia remain the least urbanised out of the developing areas (accounting to < 38% each). Latin America and the Caribbean is more than 75% urban, a level almost equal to those in Europe, Northern America and Japan (all are between 75 and 79%).

## 1.3 INDIA'S URBANISATION SCENARIO

In India Urbanization is taking place at a very high rate, currently **34.47% (46,02,49,853 people in 2019)** accounts to urban population of India, as per the estimates by 2051, the country's population is expected to be 170 crores. Fig; 1.3 shows a trend of a strong shift of rural population from rural areas to urban areas

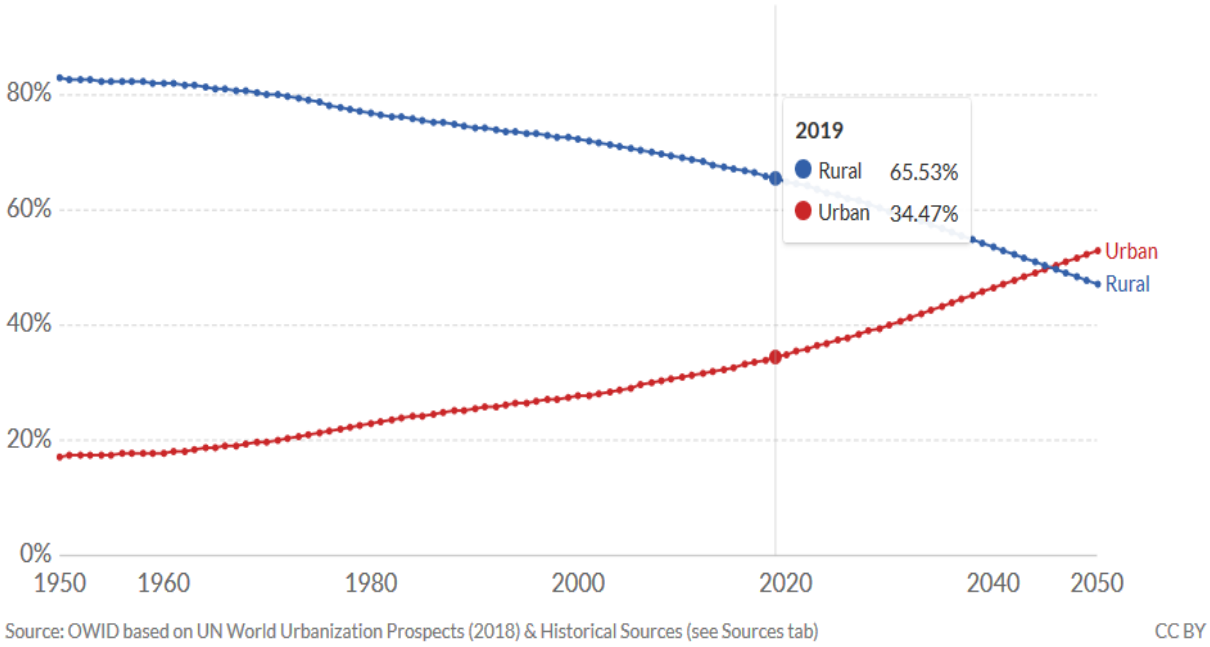



**Fig: 1.3 India's Population Trend Urban vs Rural (% of Total)**

According to Census of India, trends says - In 1901, urban population was 11.5% which increased to 28.54% in 2001 census, and lastly in 2011 census urban population of India was standing at 31.16%. (World bank, 2012)

The number of cities has also increased having a population of greater than 50 million people. In India will be having 15 cities with populations in excess of 10 million each and 85 cities with populations between 1 and 10 million apiece. That is the challenge India is confronted with. The most important factors common to India and other developing

countries are population growth, increasing urbanization, rising motorization, and low per-capita income. The total urban population of India burgeoned over the past three decades, rising from 109 million in 1971 to 160 million in 1981, 217 million in 1991, and 285 million in 2001.

By 2001, India had three megacities: Mumbai (Bombay) with 16.4 million inhabitants, Kolkata (Calcutta) with 13.2 million inhabitants, and Delhi with 12.80 million inhabitants. Chennai (Madras), Hyderabad, and Bangalore each had more than 5 million residents.

## 1.4 URBAN MOBILITY SCENARIO IN INDIA

India being a developing country and is continuously progressing in development of road infrastructure, today approximately India has a 3rd largest road network with an approximate vehicle registered till date are 230 million. The Rising private motorised vehicle owner ship and diminishing share of Non-Motorised Transport (NMT). Due to the rapid urbanisation scenario there is a high travel demand which is leading to some of the negative externalities such as road congestion, air pollution, road fatalities, and social issues of equity and security.

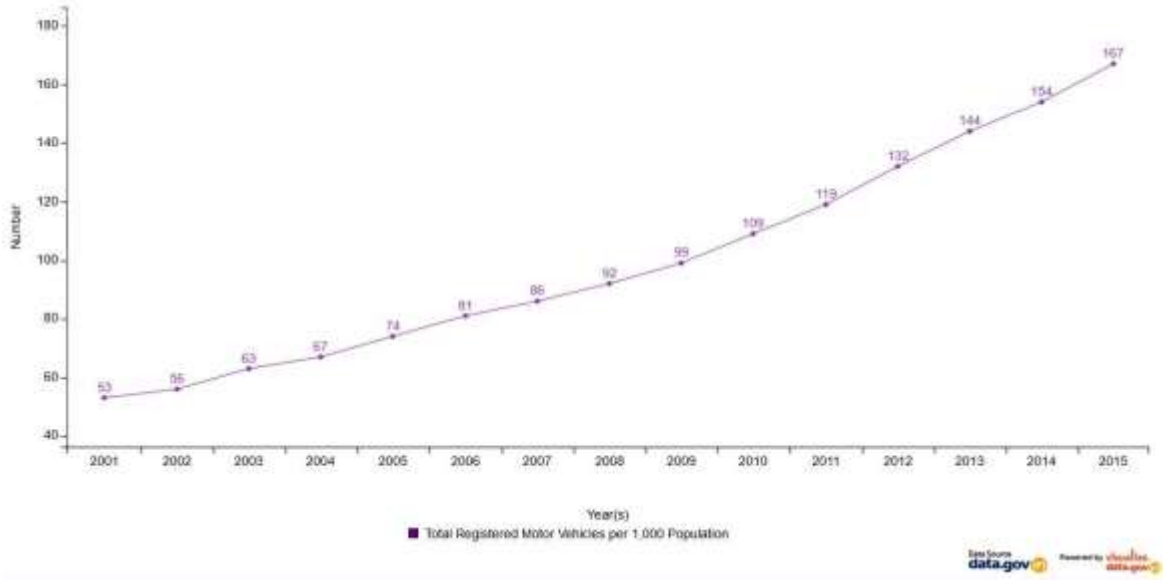



**Fig: 1.4 Vehicle Population Trend since 2001**

The number of registered motor vehicles per 1000 population was 144 in 2013. On comparison with 2010 it increased by 35 points. The number of registered motor vehicles per 1000 population was 154 in 2014 which also got increased by 10 points on comparison

to 2013. The number of registered motor vehicles per 1000 population was 167 in 2015. It increased by 13 points as compared to 2014. Hence day by day vehicular population is also increasing with the population of India.

Delhi had the highest vehicle population with almost 6.3 million vehicles, with nearly 17 million vehicles, the four big cities—Delhi, Bengaluru, Chennai and Hyderabad—alone constituted 12.30 percent of the total number vehicles in the country. Delhi, which has around 1.40 percent of the Indian population, accounts for nearly 5.00 percent of all motor vehicles. According to the statistics provided by the MORTH (Ministry of Road Transport and Highways), the annual growth rate of motor vehicle population in India has been around 10 percent during the last decade.

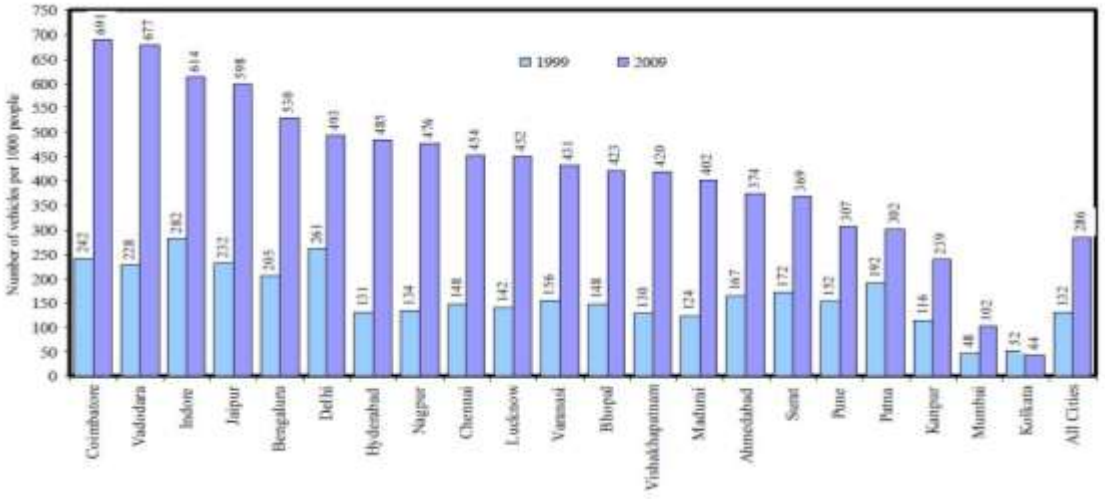



**Fig: 1.5 Number of vehicles per 1000 people in the year 2009**

A recent study by India's Ministry of Urban Development (MOUD) indicates that daily trips in the top 87 urban centres are anticipated to more than double from 228 to 482 million in 24 years (2007–2031). Hence, improving public transport is a critical component to bring efficiency in the performance of the city's transport system, improve quality of life for the city's growing population and building city's economic competitiveness.

As of current situation, the Public transport has been completely overwhelmed. Most buses and trains are overcrowded, unreliable, slow, inconvenient, uncoordinated and dangerous. Proper channelization and effective planning of transportation is essential for successful development of our community.

## 1.5 PUBLIC TRANSPORT PROFILE OF DELHI - GURUGRAM (NCR)

Gurugram has expanded significantly in the last few years resulting in a two-fold rise in population and a five-fold rise in the number of vehicles. Consequently, traffic congestion and pollution has soared and become a way of life. Keeping this in mind, Haryana Government decided to develop a metro system and finally in November 2013 Gurugram got its first metro services operational by Rapid Metro Gurgaon Limited (RMGL).

Thus, Rapid Metro provides a speedier link from NH-8 via various hubs of Cyber City & Golf Course Road to the Sikanderpur Delhi Metro station, thereby reducing commuting time substantially.

Similar to all metropolitan cities, Gurugram also have multiple modes of transport and day by day these modes of transport are increasing and improving.

**1. Gurugaman Bus Service**

Gurugaman Bus services recently launched in the month August of 2018 operated by Gurugram Metropolitan City Bus Limited (GMCBL), have a fleet of Non-AC Blue colour busses running on multiple routes with a daily frequency of 10 to 15 min on the designated routes. Gurugaman bus services are equipped with high tech technology and have mobile based application "Gurugaman" accessible on both android and ios platform, provides the information of bus routes, fare chart, live location of the bus, estimated travel time and estimated arrival time so to provide a timely service. GMCBL has constructed sheltered bus stops with all basic amenities of urban transport system.

**Fig: 1.6 Gurugaman Bus**

Gurugaman bus service have a smart card based fare collection system known as "Gurugaman Public Transit card" similar to the one used at Delhi Metro, for easy and discounted travel in the buses.


**Fig: 1.7 Gurugaman Bus Public Transit Card**

The bus services in the starts early in the morning at 6:00 AM and last upto 10:30 PM in the late night, the fleet is clean, comfortable, safe and equipped with digital information system.

**2. Personalised CNG Auto**

Personalised CNG Auto (Yellow Green Colour) also exist in the city in good number, also act a essential personalised mode of transport for last mile transport, These auto's have a big demerit that these don't have a fixed or metered fare system.

**Fig: 1.8 Yellow Green CNG Auto**

These CNG Auto's are mostly spread in all over the city, specifically locations where there are high demand, Recently in 2018 Gurugram Police has also launched a service for these

CNG auto as a prepaid auto service to regulate a fixed location fare system and avoid unnecessary fare harassment by the auto drivers. Currently prepaid Auto services are available at HUDA City Centre, MG Road Metro station and at Gurugram Railway Station.

**3. Ladies Specific PINK Colour CNG Auto**

Gurugram also have ladies specific auto, Pink in colour so as to ensure only lady passenger rides the auto and these auto's can also be booked form Prepaid Auto booth of Gurgaon Police counters available at prominent location.


**Fig: 1.9 PINK Ladies CNG Auto**

These pink autos also have all the contact information of Gurugram police in the case of emergency.

**4. OLA / UBER TAXI / G Auto / Jugnoo Auto**

Gurugram has also permitted commercial passenger taxi vehicles (Auto/LMV), which are available through mobile based or on dial a number basis so as to provide safe, comfortable, reliable, justified fare transit system to passengers. In which passenger can call the Taxi at his specific location with precepted depending upon the pickup and the drop location.


**Fig: 1.10 App Based Transit System**

**5. Shared Auto**

Shared autos are one of the oldest and common mode of transport in the millennium city Gurugram, this mode is the cheapest mode of transport additionally is highly unsafe & overcrowded. These autos have fixed charges for the fixed routes approximately 10 to 20 rupees.

**Fig: 1.11 Shared Auto**

These autos have a seating capacity of 5 to 6 passenger but generally carry more than prescribed as per Motor Vehicle Act, these autos have fixed routes but can pick and drop anywhere on the route.

**6. Bike Taxi**

Gurugram was the first city where Bike taxi was officially launched, BAXI, Rapido, OLA, UBER were the famous mobile based aggregators who successfully launched and proved to be very successful & efficient mode of travel.

**Fig: 1.12 Shared Bike-Taxi**

**7. Shuttle Bus**

A well-known fact Gurugram is city of start-ups, “Shuttl”, “OLA Shuttle” an app based commuting AC Bus service launched April 2015, this platform offered shuttle bus service to daily office commuters of Gurugram to connect with parts of Delhi NCR.


**Fig: 1.13 Shuttle Bus Services**

The platform offer’s a confirmed seat in 10 to 12-seater AC bus services with time specific and economical transit to the passenger from their office location, these bus services acted as a feeder mode to the metro station’s but very costly and little unorganized time table.

**8. Local Private Bus Aggregators**

Gurugram also multiple private bus operators which connects the passenger’s with Gurugram bus stand, Manesar and Sector 55-56 of millennium city Gurugram, Haryana.

**Fig: 1.14 Local Pvt. Bus Service**

These busses charge a minimum fare of ₹5 and goes up to ₹30 per passenger, and these busses don’t have any particular stop’s driver stops the bus anywhere in between the route to board and deboard the passengers, these busses were reported as cheapest in cost, overcrowded and unsafe to travel.

**9. E-Rickshaw / Cycle Rickshaw**

Gurugram has both battery as well as paddled Cycle rickshaw, these rickshaw beats the last mile connectivity problem for last mile commute within the radius of 2 to 3 km, these rickshaw are available on most of the passenger catchment location and charges a minimum fare of ₹ 10 or more depending upon the drop-off location.

**Fig: 1.15 E-Rickshaw / Manual Cycle Rickshaw**

**10. Rental Cycle by "Mobycyc"**

As a well-known fact Gurugram is a hotspot for all investors and startups. "Mobycyc" a mobile based booking platform for paddled as well as battery operated cycle for commuting within the New Gurugram (within 5 km).

**Fig: 1.16 Rental Cycle's operated by "Mobycyc"**

These bikes are available on rental basis ranging from ₹ 30 to ₹ 60 per hour on most of the prominent locations, the bikes are equipped with smart GPS based lock system such as these bikes don't need any cycle stand to chain and lock, these can easily be locked and unlocked with the help of scanning a QR code available on the cycle through "mobycyc" mobile android application, additionally on of the most benefitable system for a rider is it serves as

a point to point service as the rider don't have to return the cycle/bike to the same location from where it was picked instead the bike can be left anywhere at safe public area.

**11. Gurugram Railway station**

Gurugram is also connected with Northern Railway Zone on the main line of Delhi-Jaipur, station is located at Railway Road, Ashok Vihar, Gurugram at an Elevation of 215 m.


**Fig: 1.17 Gurugram Railway Station**

Many of the local passenger trains running between Rewari and Delhi also stop's Gurugram railway station, at a fare of ₹10 to ₹350 (Depending on the class) a person can travel to New Delhi on this section of railway line.

**12. Delhi Metro**

Gurugram is also connected with largest metro network of India i.e. Delhi Metro, In Gurugram region DMRC have a total of 5 metro station starting from HUDA City Centre to Gurudronacharya Metro Station, on a 48.80 km Yellow Line starting from Samaypur Badli to Huda City Centre (Gurugram).


**Fig: 1.18 Delhi Metro (Yellow Line)**

As per the standard fare of Delhi Metro, fare structure applies same in the Gurugram region, the operating hours of Metro services are from 6:00 AM to 11:45 PM, In Gurugram DMRC also have an integrated interchange station with Gurugram's privately operated Rapid Metro.

**13. Gurugram Rapid Metro**

Gurugram Rapid Metro, India's first fully privately owned and financed modern metro rail system connecting NH-8 to Delhi Metro via Cyber City and DLF Golf Course Road, Gurugram. It is a fully elevated rapid transit system and have an interchange station at Sikanderpur with Delhi Metro (Yellow Line) which connects Gurugram "Huda City Centre" with capital city New Delhi and is serving the city of Gurugram, Haryana, India

**Fig: 1.19 Gurugram Rapid Metro Interchanging with DMRC**

Gurugram Rapid metro is operated by a private company Rapid Metro Gurgaon Limited (RMGL) and have all facilities similar to Delhi Metro, Fare collection system is integrated with Delhi metro system with the help of tokens and smart cards issued by DMRC. The fare is different from the standard fare of DMRC, rapid metro fare starts with minimum of ₹20 and ranges to maximum fare up to ₹35. Operating time is from 6:00 AM to 10:00 PM.

## 1.7 PROBLEMS IN PUBLIC TRANSIT SYSTEM OF GURUGRAM (DELHI NCR)

After the comprehensive study of literature on public transportation systems globally, in developing country and India, several key issues were identified in the public transport scenario in Gurugram some of them are: -

**Ridership for Pvt. Owned Rapid Metro of Gurugram**

In the planning phase of Rapid Metro, it was estimated that the daily ridership on the rapid metro corridor will be around 1 Lac passenger per day but it doesn't likely turn to be true, as on date the rider ship is not more than 50,000 passenger per day.

**Integration of public transport modes & different departments**

Even after knowing it's a modern transit system and also operated by private concessionaire Rapid Metro Gurgaon Limited "RMGL" still things are not up to the level, no doubt station facilities and metro rail system is working as per the planning but the modes that leads the passenger to rapid metro are not well integrated, the departmental integration and coordination is not observed on the ground realities.

**Last mile connectivity**

Due to the low ridership at the station the reluctance of the different transit mode operator to align routes with the Rapid Metro in perpendicular direction to better serve the catchment areas. Several other components have their own issues.

**Modal split of urban trips**

- Maximum people use personal vehicle even in existence of metro corridor followed by share auto as the people find it a cheaper option to travel.

**Fare structure**

- The Fare structure of Rapid Metro is on the costlier side preventing ridership from middle income group users which prefer Gurugaman Bus or Share auto

## 1.8 COMPONENTS OF A TRIP

A “trip” is defined as journey between origin (access) and destination (egress) made by an individual or a commuter between two points by adopting a specified mode of travel and for a defined purpose, these modes can either be private mode or public mode or a combination of both. Trip is generated by a commuter when the need of its generation is understood, it can be either due to work related or any other reason which attracts a person to mobilize from one place to another.

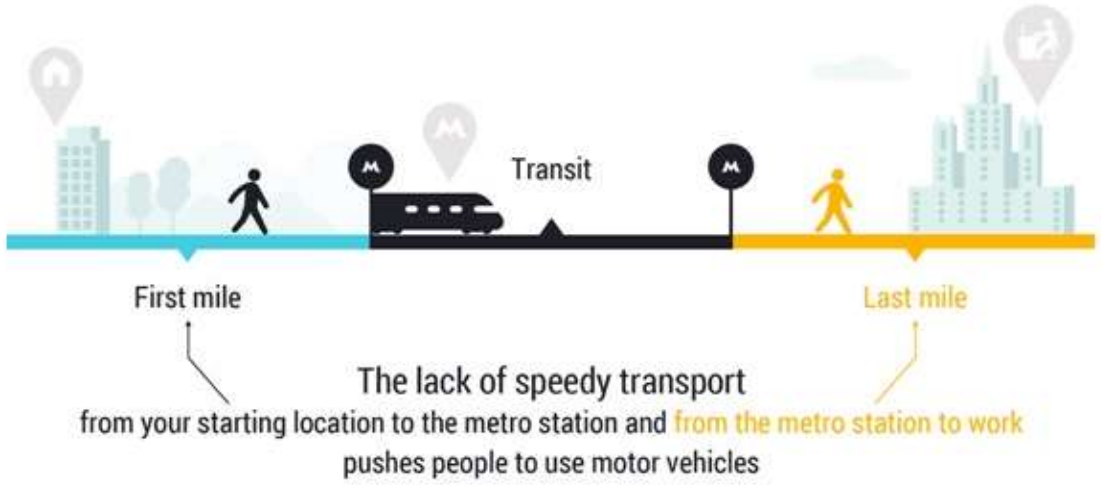



**Fig: 1.20 Components of trip**

A trip consists of access, People can use a variety of modes of transport to perform the operation, like they can walk, drive a car, take a bicycle, train, or may complete the journey involving a number of modes. Public transit agencies usually make available buses and rails that can serve as a epicentre of such trips, after that user must complete the last and first portion their journey by their own means. These means can be walk, drive a car, cycle etc. This last and first portion of the journey is referred to as first-last mile’ of the trip. As such the street and other infrastructures usually make up for the first and last mile, fall outside jurisdiction of metro authorities, but they still remain as the important components for the working of an efficient public transit organization. In other word, Metro users should be comfortable with the first-last mile challenge, and the more easily they can access the system, the more useful it becomes and its ridership will increase simultaneously.

## 1.9 CONCEPT OF LAST MILE CONNECTIVITY

In a conventional trip, the access part is usually also referred as first mile connectivity, while the egress part is said as last mile connectivity. Usually a commuter who is owning a vehicle has first mile mode available to access the public transport but may not have a connectivity for egress. Also, people who takes a drop off or lift from family members or neighbor's often have sorted out their access modes but, again the egress mode availability becomes a concern.

## 1.10 NEED AND SCOPE OF STUDY

Study aims to address these issues of Last Mile Connectivity (LMC) which is a very imperative component in attracting the commuter towards the public transit system. A newly constructed & developed public transit system of Gurugram, Rapid Metro corridor which is believed to be much neglected due to very low ridership as compared with the planning estimates. Even observing various feeder modes exists near the metro corridor, still their services are restricted to a smaller number of commuters. Most of the demand is met through Intermediate Public Transport (IPT) such as local private bus operators, Gurugaman bus, CNG auto rickshaws (which sometimes costs greater than fifty percent of the entire cost of the journey) or through cycle rickshaws and e-rickshaws, which are yet again costly and limited to certain areas. Thus, lack of combined efforts of different agencies towards integrating these IPTs with Rapid Metro Rail Systems and using their potential as an important last mile option. The inadequacy of walkable and cycle friendly environment in the city further accelerates the problem of non-acceptance for public transit system.

The important questions that this research has tried to answer are: an evaluation of distance, time, cost, comfort and space incurred in the last mile as a part of the total journey for mass transit users; their preferences and other modes available, for last mile; also, whether lack of efficient last mile mode is a decisive element in the user's choice of other transit modes and how it influences the overall efficiency of a public transit organization.

## 1.11 OBJECTIVE & SCOPE OF STUDY

1. To study the literature to understand the concept of last mile connectivity and practices across the world.
2. To study the current scenario of urban mobility along Rapid Metro Corridor in Gurugram, Haryana with respect to Last Mile Connectivity.
3. Questionnaire based commuter preference survey in order to access the station and take commuters response on the Last mile connectivity system in Gurugram.
4. Evaluation of efficiency of last mile connectivity compared with all stations of Rapid Metro of Gurugram, Haryana. Using DEA (Data envelopment Analysis) theory.
5. Policy measures formulation for improving the ridership on Gurgaon Rapid Metro based on results of this research.

# CHAPTER: 2

# 2. LITERATURE REVIEW

## 2.1 INTRODUCTION

According to the literature, various works on travel time reliability, service reliability, transit network and routing, transit scheduling, Integration of public transport systems, performance evaluation , Urban public transport, spatial interconnectivity, last mile connectivity by the use of non-motorized transport , Data Envelopment Analysis (DEA), based analysis of various mobility related problems, sustainable concepts related to efficient functioning of the MMTS. The following are several sections including research publications for the review of literature within these specific sections.

## 2.2 RESEARCH PAPERS

**1. Nebiyou T. et al. (2016)** studied the role of last mile connectivity in the modal choice decision of the passengers. They identified that due to improper connectivity between origin and destination points and the public transit facility, the LMC problem arises. Apart from considering the conventional physical distance and walkability corridor around the transit stops, they have also considered availability of transit options for LMC, accessibility to place of work, costs incurred in parking, pedestrian walking environment and Pedestrian safety from conflict with vehicular traffic along with pedestrian corridor safety from street level crime. They have utilized a discrete choice model in order to find out the way in which the above mentioned factors contribute to the LMC problem. Their results indicate that if safety aspect is enhanced in the transit access trip, more ridership could be roped in for public transit. Improved accessibility for destination boosts the transit use drastically.

**2. Chidambra, Gupta Sanjay, 2015** In this paper, study is made to understand the potential use of Non-Motorized Transport (NMT) due to the absence of effective policy to encourage the use of public transport for the Last Mile Connectivity (LMC), Delhi Metro stations namely Rajiv Chowk, Chandini Chowk, Noida City Centre, Vishwavidyalay, Chattarpur

and Akshardham were taken as the study area, Last Mile Characteristics are explained depending upon the users of metro with an empirical study.

Analysis explains access and dispersal patterns vary from the metro station depending upon the geometric environment available around the metro station, walking is found to be the predominant mode of access and dispersal from the metro station which were located in the dense & congested location, while dependence on mechanized hired services (Auto, Taxi, Rickshaw) and personal motorized vehicles were observed in less populated as well as congested location.

**3. Chidambara & Gupta Sanjay, 2018** They attempted to study the "walk" choice of users based upon several other considerable factors such as their socio-economic characteristics, trip based characteristics etc. The effect of the condition of pedestrian environment on the choice to walk was also evaluated with respect to considering walk as the last mile connectivity option. They have attempted to rank the transit stations w.r.t various walkability characteristics. Their results reveal that the walkability environment plays a crucial role in making walking a preferable choice for commuters for the last mile connectivity. In the absence of a good walkable corridor, the commuters might travel from unsustainable mechanised modes. Some of their results are shared as follows.

**Table: 2.1 Case study stations operational characteristics and surrounding context**

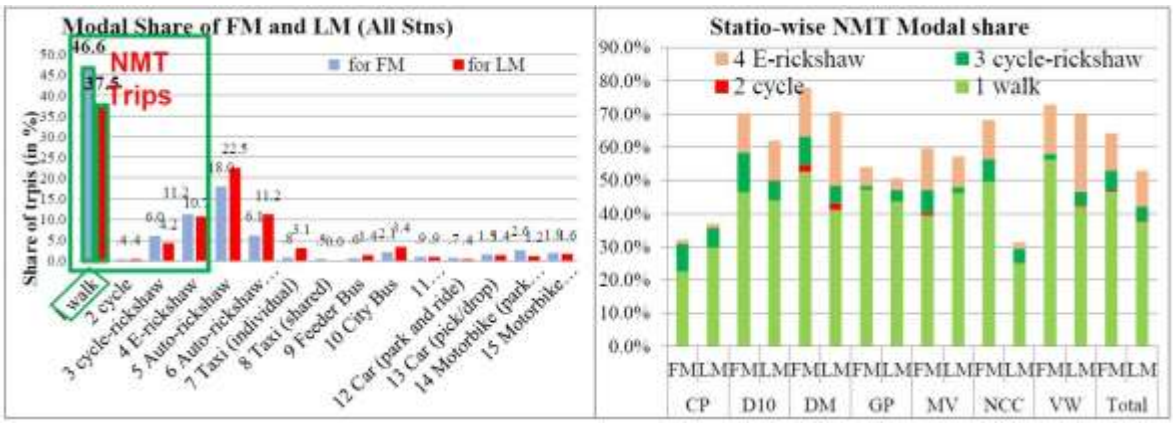
| **Station Name** | | **Operational Characteristics** | | **Physical Context** | |
|---|---|---|---|---|---|
| Avg.Daily Ridership* (April'17) | Typology | Last Mile Transport Supply | | Adjoining Land use | Nature of Planning |
| Mayur Vihar-I (MV) | 19,413 | Mid-block | Cycle-rick, E-rick, Auto-rick, shared auto, Feeder bus | Residential | Planned |
| Dwarka Sec-10 (D10) | 9,761 | Midblock | Cycle-rick, E-rick, Auto-rick, shared auto, | Residential Institutional | Planned |
| Noida City Centre | 36,733 | Terminal | Cycle-rick, E-rick, Auto-rick, shared | Commercial (partially | Planned, Urban village |

| | | | | | |
|---|---|---|---|---|---|
| (NCC) | | | auto, City bus, Chartered bus | developed), Residential | |
| Dwarka Mor (DM) | 42,928 | Midblock (acting as terminal) | Cycle-rick, E-rick, Auto-rick, shared auto, Feeder bus, City bus, Chartered bus | Commercial Residential | Planned, Urban village |
| Chhatarpur (CP) | 36,036 | Midblock (Delhi outskirts) | Cycle-rick, Auto-rick, shared auto, Feeder bus | Residential Commercial (informal) | Planned, Urban village |
| Vishwavidyalaya (VW) | 25,593 | Mid-block | Cycle-rick, E-rick, Auto-rick, shared auto, City bus, PBS | Residential Institutional | Planned |
| Green Park (GP) | 27,900 | Mid-block | Cycle-rick, Auto-rick, Feeder bus | Residential Institutional Commercial | Planned |

**Table: 2.2 Trip Characteristics of Transit Journey Components**

| **Last Mile Components** | | **Time (in minutes)** | | **Cost (in Rs.)** | | **Distance (in kms)** | |
|---|---|---|---|---|---|---|---|
| | | Mean | % | Mean | % | Mean | % |
| 1 | FM | 12 | 18 | 9 | 19 | 1.6 | 8.0 |
| 2 | MH | 40 | 61 | 25 | 52 | 16.5 | 82.5 |
| 3 | LM | 13 | 20 | 15 | 32 | 2.0 | 10.0 |
| 1+3 | FM+LM | 25 | 39 | 23 | 48 | 3.5 | 17.5 |
| 2+(1+3) | Total Trip = MH+(FM+LM) | 65 | 100 | 48 | 100 | 20.1 | 100 |

The predominant mode for covering both FM and LM, as can be seen from Fig.2.1 is 'walk', followed by auto-rickshaws (both individual and shared) and then by e-rickshaws.




Source: Author, Primary Survey, 2017

**Fig: 2.1 Modal Share of Trips (in %)**

Use of NMT is more for First Mile trips (64.1%) as compared to LMC trips (52.8%). Likewise, there exists higher share of pedestrians in FM (46.6%) in comparison to LM (37.6%). 62% of FM trips have origins at home-end while only 33% of LM trips have destinations at home-ends. Amongst the stations, DM and VW have the highest shares of NMT trips both for FM & LM.

Gender and Household income categories are both important variables in walk choice for FM as well as for LM. A closer inspection of data shows that men walk equally at both ends of the trip whereas women prefer an IPT to cover the LM.

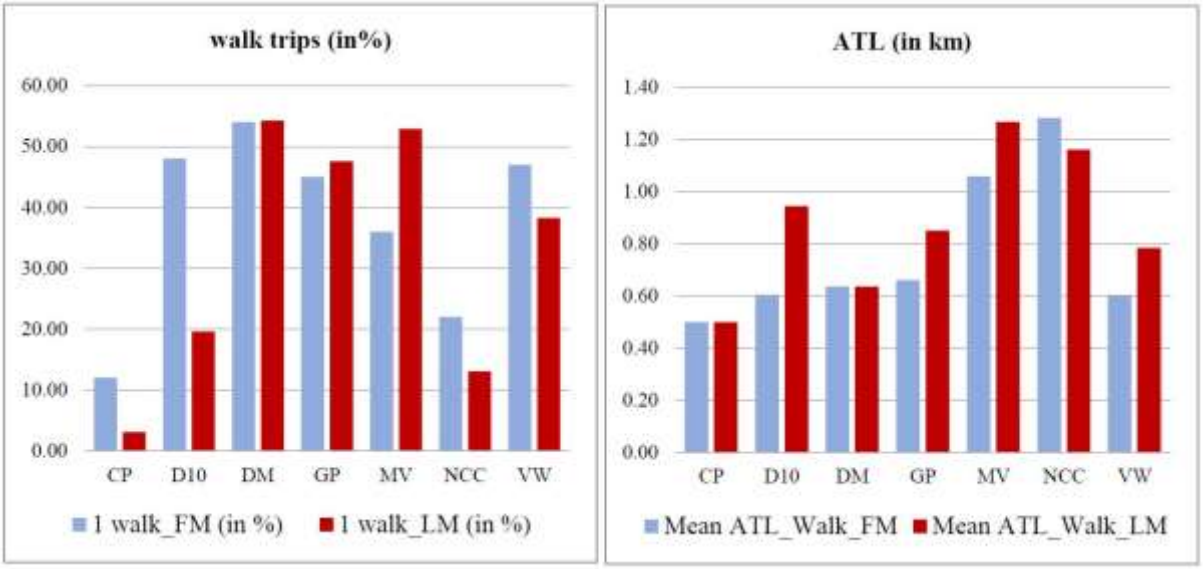



**Fig: 2.2 FM/LM walk trip characteristics of case stations**

**4. Hensher, D.A. et al.. (2011)** conducted a research that emphasizes on the commuter subdivision and develops an innovative stated choice investigation in which passengers compare the planned new Metro with current available mode based alternatives for access, line haul and egress stages, with a specific emphasis on the assimilation of crowding symbolized by the availability of a seat vs. standing in present and the new public transit modes.

In 2009, the government of New South Wales declared that there would be a proceeding with a feasibility report to identify the ridership potential of a new Metro train-based system for Sydney. A new modal choice study was carried out to establish the contributory role of traditional characteristics such as travel times and prices (also, reliability) but also to some degree neglected influences like over-crowding, where the later plays an important role in the calculation of capacity requirements at the railway terminals. The error component choice model has been presented together with approximations of mode-specific inclination to pay for travel time components, crowding and service frequency and that the latter is to be expressed in terms of probability of acquiring a seat and the probability of escaping standing.

**5. Tsamboulas, D.A. (2006)** measured the performance of transport systems functioning under dissimilar regulatory systems is a topic of substantial interest in the research done so far. The aim of this research is to examine the performance features and factors influencing this performance aimed at European transport systems operating in very different regulatory environs. The early results of data envelopment analysis show that privately operated modes tend to be efficient whilst publicly operated modes tend to be more effective. Transport workers in cities wherever an open entry method of competition has been announced were found to carry out both efficiently and effectually. Additionally, as the Tobit regressions concentrated on the consequence of ownership show, most systems in the example demonstration show a optimistic trend in both efficacy and efficiency.

**6. Sreehari, M.N.** studied the Bangalore Metropolitan Transport Corporation has been lauded for its good coverage and services under “the agenda of “Passenger satisfaction” with its progressive approach and proactive standpoint.” The diagonally connected metro grid connects the city in a spatially better manner and also encompasses the core ring roads,

the outer and the inner ring roads. The number of buses required in future has been estimated to be around 5000 for covering 1394 Sq. Kilometers of area. The BMTC caters to approximately 3.5 million passenger trips on a daily basis. A study was conducted where passenger perception over different parameters contributing to the service of BMTC buses were evaluated as shown in table 2.3 and figure 2.3.

**Table: 2.3 Passenger Perception contributing to the service of BMTC buses**

| S.No. | Attribute | Percentage | Ranking |
|---|---|---|---|
| 1. | Punctuality/Reliability | 46 | 1 |
| 2. | Accessibility (walking distance) | 28 | 2 |
| 3. | Travel Cost | 14 | 3 |
| 4. | Safety | 4 | 4 |
| 5. | Comfort | 8 | 5 |

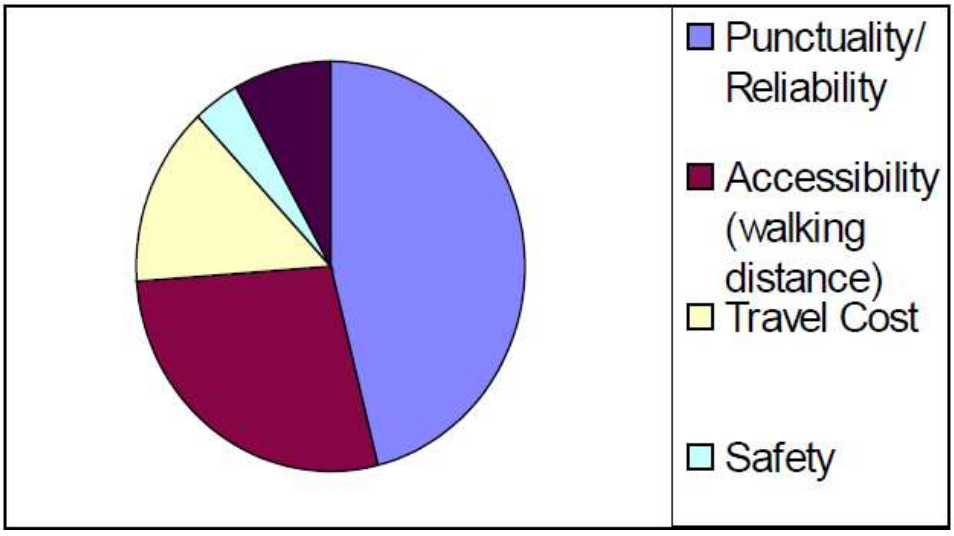



**Fig: 2.3 Passenger Perception composition**

The alternative option to the BMTC in the wake of upcoming metro system in Bangalore were also evaluated on different attributes as shown in table 2.4 and figure 2.4.

**Table: 2.4 Qualitative Comparison of Bus and Auto**

| S. No. | Factors | Bus | Autos |
|---|---|---|---|
| 1. | Coverage of the network/Connectivity | Good | Very Good |
| 2. | Punctuality | Good | Very Good |
| 3. | Accessibility | Good | Very Good |
| 4. | Travel Cost | Excellent | Fair |
| 5. | Safety and Comfort | Very Good | Average |

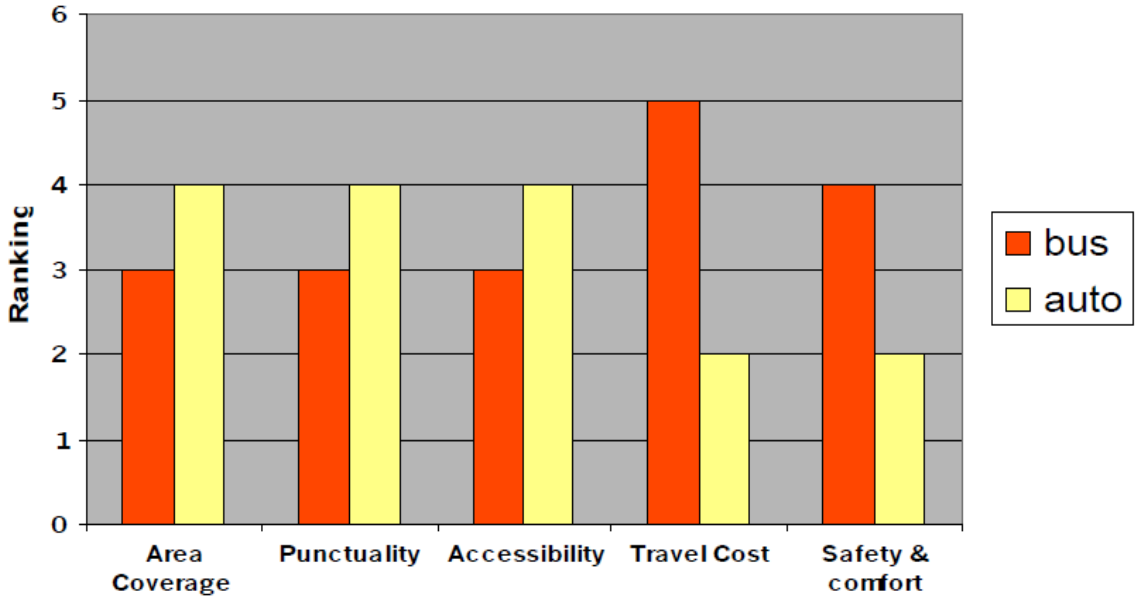



**Fig: 2.4 Ranking based comparison**

After these evaluation and introspective activities were carried out it was realized that the following improvements in the system shall contribute to the betterment of the system: -

- More extensive spatial coverage can be ensured in the grid routes in order to make the BMTC more popular.
- More dedicated corridors for BMTC buses can upscale the quality of service or an exclusive elevated road could be constructed to give a congestion free speedy ride to passengers.

- The bus services can undergo a design uplift to make it more appealing to the passengers, also infrastructural changes at interchange stations/stops could be made to make the service more lucrative.
- The simulation packages can be used to study the impacts of various parameter augmentations.
- Waiting time can be reduced by increasing the number of buses and by reducing the fleet.
- The fare structure could be made more competitive.

**7. Eboli L. et al., (2014)** had suggested an approach for evaluating transportation service quality. It was based on the use of both commuter perceptions and transport agency performance measures including the key aspects portraying a transport service. The heterogeneity of these opinions is because of the qualitative nature of several aspects depicting the services and sensitivities. These results have revealed that the variance of objective pointers is lesser than the variance of the subjective indicators.

**8. Karlaftis M.G. et al. (2012),** have discussed 3 major evaluation-based issues, first one questions the similarity in the results produced from different methodologies adopted for efficiency assessment. The second question tries to find a correlation between transit performance, effectiveness and efficiency. The third question tries to adjudge the sensitivity of the methodological specifications which are being used to find the organizational regimes like the contracting, public operations etc. They used data from 15 European Transit systems for a duration of 10 years (1990-2000). The results achieved by them show that the findings regarding the efficiency scores are sensitive towards the specific models used and also that the effectiveness is negatively related to efficiency. These findings can have implications of future policies to a good level.

**9. Guo Z. et al., (2011),** assessed the cost of transfer inconvenience in public transport systems: a case study of London Underground. This research develops a method to assess transfer cost and to identify ways to reduce it. The different transfer components studied include transfer walking, waiting time and penalty etc. the method is applied to London

underground with a emphasis on 17 major transfer stops and 303 transfer activities. The results display a huge cost enforced by transfers in a public transit system, and recommend that enhancing the transfer-based commuter experience should considerably benefit Public Transit.

**10. Diana M. (2012),** studied the customer satisfaction for the public transport service. Nine satisfaction measures of urban transit are taken into consideration viz. service frequency, punctuality, possibility of finding sitting place, speed of the service, cleanliness of the vehicles, comfort whereas walking at bus stops, connectivity with other municipalities, convenience of schedules, cost of the ticket, municipality where the household is located and frequency of the use of urban public transport. Samples were taken from multimodal travelers in Italy. Results show that higher level of passenger satisfaction existed in smaller towns when compared to the bigger cities. Also, there was no correlation observed between the satisfaction levels for the service and frequency of use.

**11. Mishra S. et al. (2012),** carried out a study in the Washington D.C. area with the use of GIS mapping techniques in order to evaluate the connectivity parameters of multimodal transportation such as all levels of transit service coverage, integrating routes, schedules, socioeconomic, demographic and spatial activity patterns. connectivity was used as an objective to quantify the transport service in terms of ranking transit locations for aid, providing service delivery plans, particularly for areas with huge multi-jurisdictional, multimodal transit networks, providing an pointer of multi-level transport capacity for forecasting purposes, judging the effectiveness of node/station ranking and identifying location with highest connectivity while choosing public transport as a mode of travel. The planned analysis gives reliable parameters that could be utilized as devices for finding out the connectivity of a multimodal transit system.

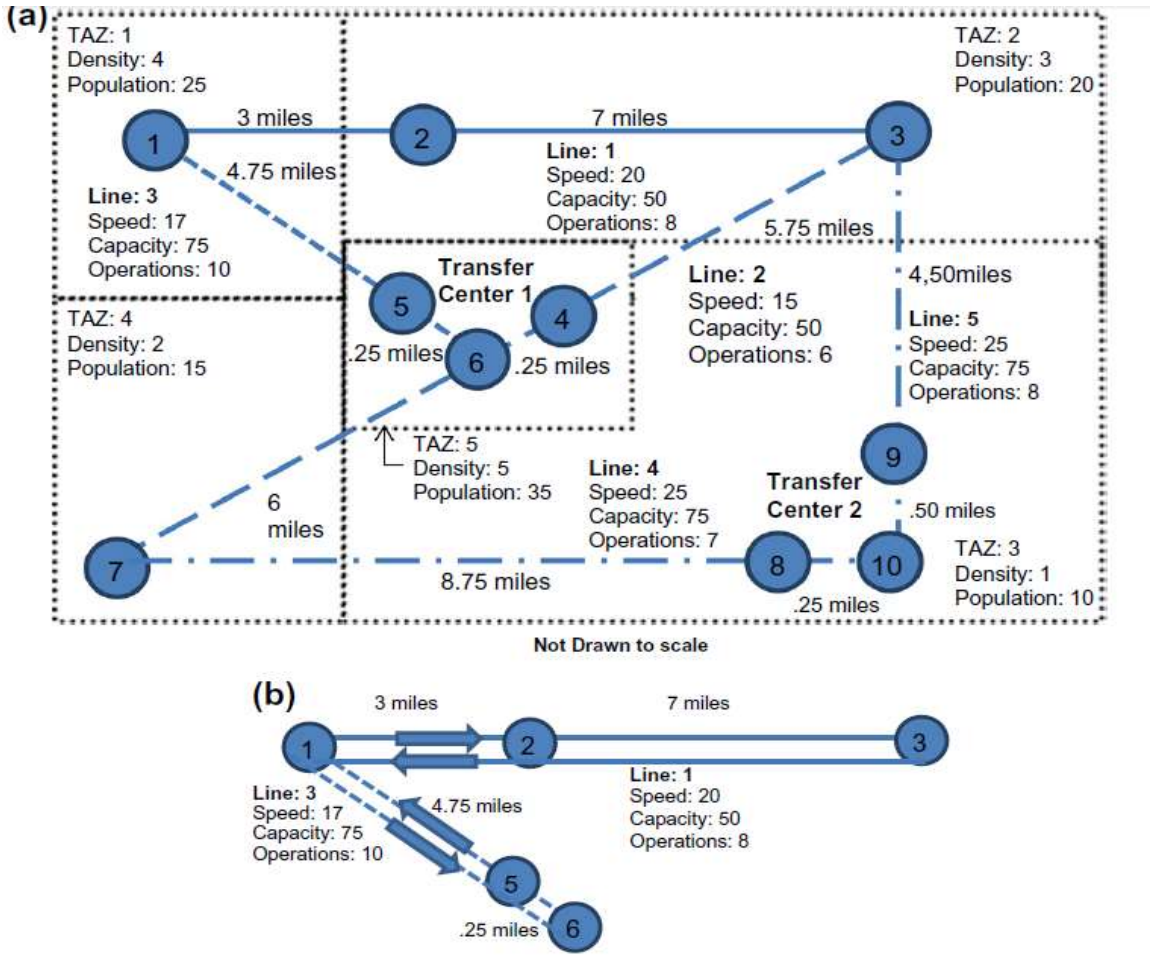



**Fig: 2.5 (a) Example of transit system. (b) Zoomed version of node1.**

**12. Krygsman S. and Dijst M. et al. (2004),** emphasized on access and egress connectivity of an urban public transport system and a comprehensive travel diary survey is conducted to collect detailed travel time estimations. The results recommend that access and egress timings are a function of access and egress modes and trip direction rather than of sociodemographic features. Land use also imparts a nonlinear impact on the twin parameters. Access and egress times surge with growing trip time but this proliferation is not as durable as the line haul time and as a consequence the interconnectivity ratio decays as trip time rises. For most multimodal trips the ratio falls within the range of 0.2-0.5. The regression results also have some implications for predicting trip travel time.

**13. Kumar P. et al. (2011),** recognized the susceptible characteristics of road consumers' w.r.t Delhi while on a multimodal trip. One cluster of road users which form a ecological low cost feeder mode to multi modal transit systems are the Vulnerable Road Users (VRUs), namely, bicyclists, cycle rickshaws and pedestrians (BCPs). A key survey to evaluate the vulnerability of road consumers at Delhi's bus-metro interchange, Kashmere Gate Delhi Metro Station, exposed that mixing BCPs with motorized vehicles, followed by the poor roller stability of cycle rickshaws, pose the attributes that increase their vulnerability. Therefore, several enhancement measures have been recommended. Additionally, the National Road Safety Bill and National Transport Safety Policy are being deliberated by the Government of India, to run policy choices for better safety and movement of VRUs.

**14. Rastogi Rajat (2010),** studied the catchment areas of suburban Mumbai to see the willingness to shift to public transit mode by using NMT modes like walking and bicycle for the egress and access. The emphasis was laid on the environmental benefits of use and the enhancement in facilities and the commuters were asked about the willingness/non-willingness for each of the options. Further the share in the willingness and the potential to actually shift was determined to examine the situation. It was observed that the socio-economic characteristics played a good role in deciding the attitude of the commuter towards bicycling and walking. LIG and MIG people were more willing towards these modes than HIG. Around 10-12 % of potential to shift was expected in that area.

**15. Alshalalfah B.W. et al. (2007),** discovered the association between walk based access distance to transit services and various attributes of the transit service and commuters in Toronto. The statistics used in the study involved archives of transit journeys made in the morning peak period (6-9 a.m.) on a typical week day. The outcomes demonstrate that the complicated transit route network in the downtown region results in lower walk-based access distances as compared to the other parts of the metropolitan. Likewise, dwelling category of the household, sum of vehicles available in the family, and transit service regularity show a significant association with access distance in Toronto. Altogether, it was figured out that about 60% of public transportation users in Toronto thrive within the transit based service area of 300 m airline distance presumed by the transit service provider. The outcomes show that individuals in Toronto are keen to walk more to access transit than presumed present standards for transit service regions.

# CHAPTER 3

# 3. METHDOLOGY

In this chapter we discussed about the study area, the conditions prevailing there. We will also discuss the strategy to do the analysis for the better understanding the study area for the fulfillment of the objective of the study.

## 3.1 DESCRIPTION OF THE STUDY AREA

The study was carried in the millennium city Gurugram (28°28'50.65"N, 77° 5'39.48"E) in the state of Haryana, India, Fig: 3.1, Gurugram which is located very close to Capital City of India, New Delhi and is one of the major developing megacities in the world.


**Fig: 3.1 Gurugram-Delhi NCR Region**

Due to rapid urbanization, development of IT sector the city saw a large-scale migration over the last decade. As Gurugram is located close to the International Airport of Delhi, it became the first choice of all Multinational Companies, Business hubs to settle their regional office close to nations capital. Development of cybercity by the private builder DLF India, on the border of Delhi-Haryana over the National Highway No.8, houses many multinational companies like Deloitte, KPMG, IBM, Ericsson, Accenture, Samsung etc.

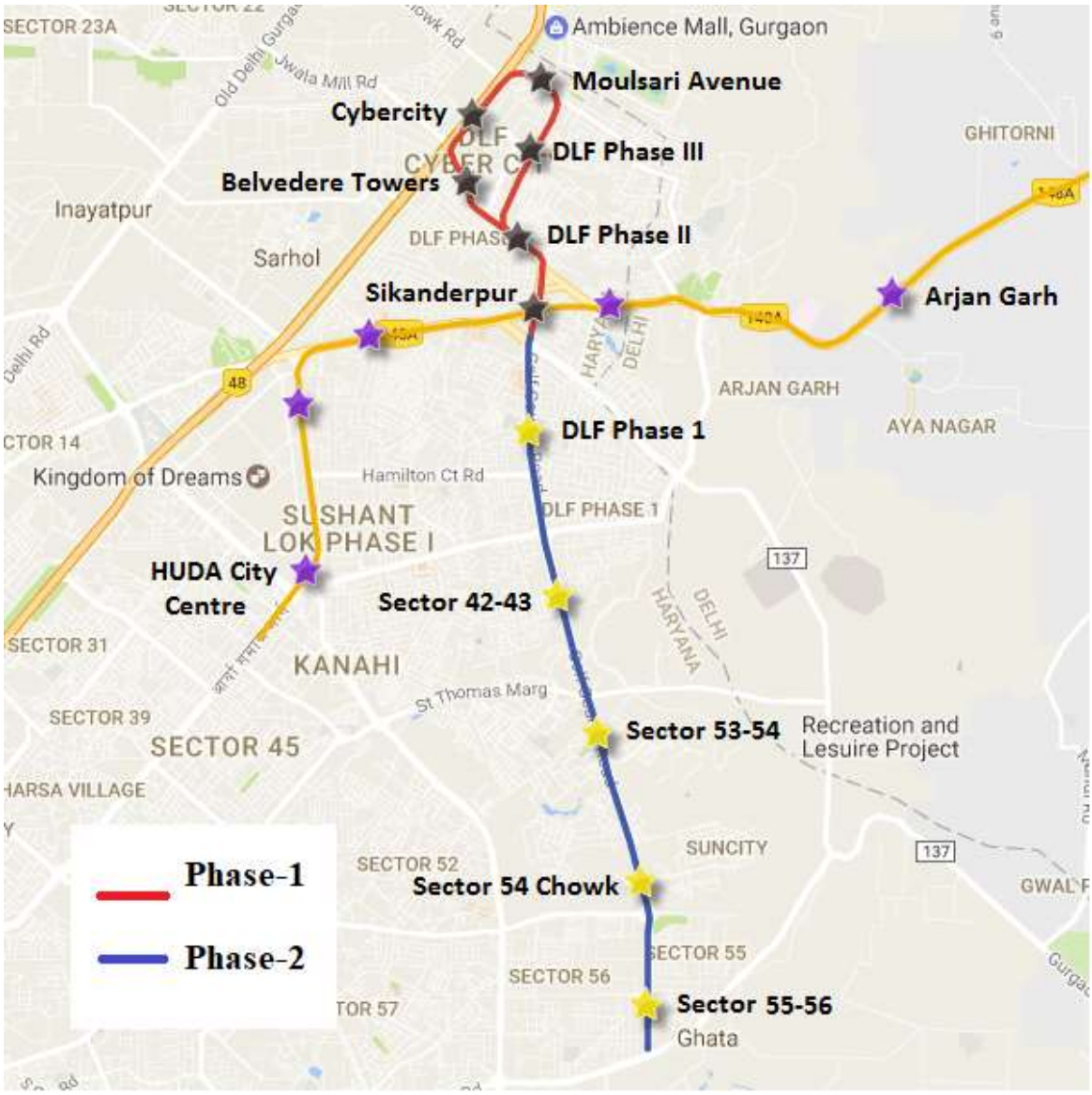



**Fig: 3.2 Rapid Metro Corridor**

Gurugram Rapid Metro, India's first fully privately owned and financed modern metro rail system connecting NH-8 to Delhi Metro via Cyber City and DLF Golf Course Road, Gurugram. It is a fully elevated rapid transit system and have an interchange station at Sikanderpur with Delhi Metro (Yellow Line) which connects Gurugram "Huda City Centre" with capital city New Delhi and is serving the city of Gurugram, Haryana, India. Currently Gurugram Rapid Metro has a total elevated corridor length of 11.70 km with 11 elevated metro stations (Fig: 3.2) on a standard gauge track. Rapid Metro Gurgaon Limited (RMGL) constructed in two phases, the very first phase of 5.10 km length was constructed and became functional in November 2013 consisting 6 metro stations (Sikanderpur, DLF

Phase-2, Belvedere Tower, Indusland Bank Cyber City, Moulsari Avenue and DLF Phase-3). The metro section between DLF Phase 2 and Sector 55-56 station is double-tracked, while the remaining stations are served by a single-track loop.

The second phase of Rapid Metro Gurgaon Limited (RMGL) became operational in April 2017 comprising of 6.60 km length extending towards the south connecting with urban residential area of Gurugram from Sikanderpur to Sector 55-56 having 5 stations (DLF Phase-1, Sector 42-43, Vivo Sector 53-54, AIT Sector 54 Chowk and Sector 55-56) which mostly runs over DLF Golf Course Road. Rapid Metro Gurgaon Limited (RMGL) also have an elevated metro depot at AIT Sector 54 Chowk Gurgaon provides for a large workshop for the maintenance of the Metro coaches. Metro Depot is also designed for an office space of about 30,000 $m^2$ under the elevated deck of rolling stock.

## 3.2 METHODOLOGY OF DATA COLLECTION

The data collection was done in three survey formats

1. Rapid Metro user survey for commuters using Rapid Metro in their daily commute, the data was collected from commuters using questionnaire-based surveys so as to know their preferences on the basis of commuter's demographic characteristic, information of their travel distances, mode choice and level of satisfaction with the overall daily commuting system.
2. Inventory Survey of all Rapid Metro stations considering all the crucial elements which play a vital role in fulfilling the last mile connectivity i.e. Facilities like parking, availability of clean drinking water, space for waiting area, safety & lighting during day and night etc.
3. Non – Rapid Metro user survey was conducted around different locations approximately within the radial distance of 2.5 km from Rapid metro corridor like parking lots, shopping complexes, commercial/office centers, bus stops, taxi stands, auto stands and even fuel pumps. As these locations can clearly explain the reason for not adopting rapid metro services as their commute choice and the need for improvement required, so as to increase the foot count on the heavy cost involved transit system with an increased existing catchment area.

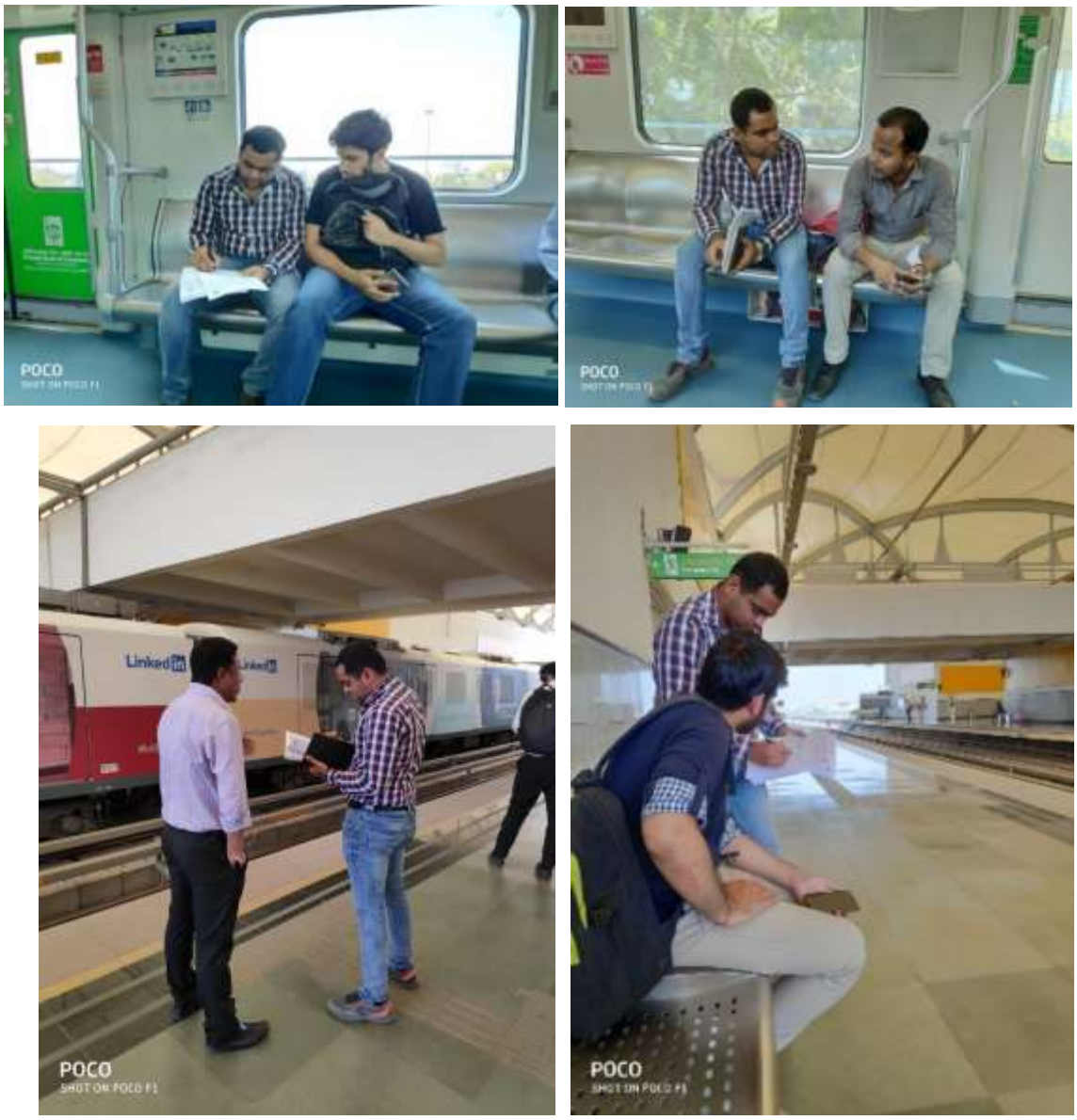



**Fig: 3.3 Commuter Perception Survey (Interview Method)**

## 3.2 METHODOLOGY OF DATA COLLECTION FOR NON-METRO USER

Survey locations were decided on the basis of 2.5 km radial distance from every rapid metro station, approximately 5 to 6 most prominent transit-oriented location were taken as our survey locations and questionnaire-based survey forms were prepared & road side commuter who were waiting or walking towards their location were interviewed, Table 3.1 to Table 3.11 explains the reason for selecting different location's for the mentioned station.

**Table: 3.1 Survey Location for Indusland Cybercity**

| S. No. | Location | Reason for selection |
|---|---|---|
| 1 | DLF Gateway Tower, Gurugram | Commercial office space building, Having a very big parking space in near to building |
| 2 | Cyber Hub, Cybercity, Gurugram | Food court for cybercity, having a high foot fall as it is also known for social gatherings. |
| 3 | Udyog Vihar Phase-4, Gurugram, Haryana | This is a Automobile Sector and have many supply and research units for Maruti Udyog Ltd, office spaces for Bharti Airtel, Deliote also exists in this sector |
| 4 | Udyog Vihar Phase-5, Gurugram, Haryana | This is a commercial sector and have many governments offices (Like income tax dept, SIDBI Finance etc) |
| 5 | Unitech Info Space, Old Delhi-Gurugram Road | This is an IT Office space built by Unitech and have MNC offices with minimum employee count of two to three thousand. |
| 6 | Sector-22 Market, Gurugram | Residential Sector Market with brand's like Dominos, Geetanjali Saloon. |

**Table: 3.2 Survey Location for Moulsari Avenue**

| S. No. | Location | Reason for selection |
|---|---|---|
| 1 | Ambience Mall | India's Largest Mall of about 1 km in length and have a very high footfall of daily shoppers. |
| 2 | Udyog Vihar Phase-1, Gurugram, Haryana | Industrial Sector with many Large - scale industries |
| 3 | Udyog Vihar Phase-2, Gurugram, Haryana | Land use for this sector is industrial but have both commercial as well as industrial units. |
| 4 | Udyog Vihar Phase-3, Gurugram, Haryana | Land use for this sector is both commercial as well as industrial and this sector have many Multinational company's corporate office space |
| 5 | DLF Phase-3 (V-Block) | Residential Colony having good number of luxury bungalows and also have a luxuries club known as DLF City Club. |

**Table: 3.3 Survey Location for DLF Phase-3**

| S. No. | Location | Reason for selection |
|---|---|---|
| 1 | DLF Phase-3 (U-Block) | Residential Colony having good number of luxury bungalows and also have a luxuries club known as DLF City Club. |
| 2 | DLF Cyber Greens, Building 7A, 9B | Commercial office space with many MNC, having more than 5,000 employees. |
| 3 | Cyber City, RBC Office main gate and parking | Commercial office space with many MNC, having more than 5,000 employees. |
| 4 | Village Nathupur | Modern village with residency converted to paying guest houses have many employees residing as the cyber city is located very close. |

**Table: 3.4 Survey Location for DLF Phase-2**

| S. No. | Location | Reason for selection |
|---|---|---|
| 1 | DLF Phase-2 Parking | Parking space for cars and scooters (300 cars approx.) |
| 2 | American Express Office Building | This is also MNC building having a multilevel car parking with the building. |
| 3 | Indian Oil Petrol Pump of Cybercity | Single and only fuel station in the locality hence gets a good number of vehicles |
| 4 | Open Space Parking on DLF Ph-2 side | Unauthorized parking space where all taxi's wait for rides (OLA/Uber) |

**Table: 3.5 Survey Location for Belvedere Tower's**

| S. No. | Location | Reason for selection |
|---|---|---|
| 1 | DLF Cyber City Building 10 | Commercial office space, having MNC like Deloitte, KPMG, Toshiba etc. |
| 2 | DLF Cyber City open parking | Car parking space for cyber city registered user's only |
| 3 | Nestle India Office building and open parking on DLF Ph-2 | Commercial office having more than 1,000 employees. |
| 4 | Foot over bridge crossing on NH-8 | FOB Connecting Udyog Vihar with NH-8 |
| 5 | Belvedere Tower's Entrance gate | Residential housing society with almost 100% occupancy |

**Table: 3.6 Survey Location for Sikanderpur**

| S. No. | Location | Reason for selection |
|---|---|---|
| 1 | Delhi Metro Parking on Sikanderpur | This is the most prominent station of Gurugram as it is an interchange station for delhi metro with rapid metro, the parking lot is generally crowded during whole day (15-18 Hours) |
| 2 | Parked vehicles on Service Road of MG Road Both sides | Many taxi, auto vehicles were parked and waiting for passenger's so these location also help in getting information of non user's of metro |
| 3 | Sikanderpur Market | It is a prominent and highly congested market dealing in all Sanatory, Electrical and all construction material, have a high foot count of professional skilled workers and contractors |
| 4 | City Court Shopping Complex Parking at Sikanderpur | It is a mall cum shopping complex have a two-level basement parking, having many offices, banks, shops |
| 5 | DLF Phase-2 Shopping Market | This is residential society market, and have many small offices and shops for all daily needs, food outlets |

**Table: 3.7 Survey Location for DLF Phase-1**

| S. No. | Location | Reason for selection |
|---|---|---|
| 1 | Mega Mall Parking, DLF Ph-4 | Shopping mall have a 3 level basement parking, having multiband shops and cinema. |
| 2 | Vehicles parked around the station | Many taxi/Pvt. Vehicles are parked around the road side waiting for passenger's |
| 3 | Hindustan petrol pump on DLF Phase-1 | This petrol pump is located on a stone throwing distance from DLF phase-1 metro station so the car users could be interviewed while their vehicle is refueled |
| 4 | Qutab Plaza Market, DLF-1 | This is residential society market, and have many small offices and shops for all daily needs, food outlets |
| 5 | Arjun Marg, DLF Ph-1 | One of the most high-end society prominent road also have a shopping mall located |
| 6 | Galleria Market Parking, DLF Ph-4 | High end Commercial shopping complex with many shop cum office space |
| 7 | Sector-27, MLA Flats | Residential Society having a residential flat for 100 families approximately |

**Table: 3.8 Survey Location for Sector-43**

| S. No. | Location | Reason for selection |
|---|---|---|
| 1 | Sector-42,43, DLF Phase-4 and Sushant lok-1 | Residential housing society with more than 3000 families |
| 2 | Supermart-1&2, DLF-4, Vyapar Kendra Sushant Lok C & B Block | Commercial shopping complex with many shop cum office space |
| 3 | The Global Foyer Mall, Vipul Office spaces | Shopping cum office space having many big restaurants |
| 4 | DLF Centre Court | Office space for Ernst & Young, Dell India |
| 5 | The Magnolias, The Aralias | High end residential society with more than 1000 families and also have a golf course within its periphery |
| 6 | The Anya Hotel entrance gate | 5 star hotel located very close to metro station |

**Table: 3.9 Survey Location for Vivo Sector 53-54**

| S. No. | Location | Reason for selection |
|---|---|---|
| 1 | The Horizon, American Express entrance gate & Surface Parking | Commercial office space with a daily foot fall of more than 2000 employees |
| 2 | The South point Mall and The Shopping Mall on Golf Corse Road | Commercial office cum shopping space with famous din in restaurants like subway, pizza hut, KFC, Le Marche. |
| 3 | Paras Hospital, Sushant Lok E & C Block | A 250 bedded hospital on the main road of Sushant Lok E & C, Block having a residential society of more than 1000 families |
| 4 | Paras Downtown Centre | Commercial office space with many office spaces and Banks |
| 5 | The Blaire, Parsvanatha Exotica, Willington Estate and DLF-5 Housing society | High end residential society having high occupancies (Approx. 1000 families) |
| 6 | Carlton Estate, Westend heights entrance Gate | Residential Society having a residential flat for 100 families approximately |

**Table: 3.10 Survey Location for AIT Chowk / Sector -54**

| S. No. | Location | Reason for selection |
|---|---|---|
| 1 | Ansal's University | A premium high-tech university with almost 1000 students daily footfall |
| 2 | IILM Institute of Management | A management institute with atleast 500 students daily foot fall |
| 3 | Hindustan petrol pump opposite Jalvaiyu Vihar | Highly occupied petrol pump as it is only petrol pump in the closed vicinity |
| 4 | Suncity Residential Housing Society | Residential society, with large corporate tower and shopping complex |
| 5 | Parked Vehicles Along AIT Chowk | As the road is a 16 lane expressway, having a high vehicular count |
| 6 | Tau Devilal Park | Famous Biodiversity park opposite village wazirabad |

**Table: 3.11 Survey Location for Sector 55-56**

| S. No. | Location | Reason for selection |
|---|---|---|
| 1 | Pioneer Urban Square Parking | Commercial hub, it's a corporate tower building for many MNC offices |
| 2 | Hong Kong Bazar Surface Parking | Commercial shopping complex, having banks, sweetshops, offices hence a good footfall |
| 3 | Hotel Double Tree Surrounding parking location | 3 star hotel property, host many corporate as well as meeting's |
| 4 | Sector 56 Market | Commercial area for daily need's shopping for all the nearby residential spaces, also property registration office "tehsil-wazirabad" also exist in the same location |
| 5 | Sector 55 Market Ansal's Tower | Commercial shopping cum office space having a good footfall |
| 6 | Ansal's Aravali Residencies | Residential housing society and having flats for more than 200 families |


**Fig: 3.4 Survey Location around Rapid Metro Corridor**

### 3.3 SAMPLE SIZE DETERMINATION

For data collection, we used standard formula targeted a sample size of at least 385, the targeted data is calculated by using the sample size calculation for large population.

$$\frac{z^2 \times p\,(1-p)}{e^2}$$

Where

N = population size

z = z-score

e = margin of error

p = standard of deviation

Gurugram has a population of 27,03,172 and taking a margin of error (e) as 5% and standard deviation (p) 50% and 95% confidence level (z-score for 95% confidence level is 1.96) we calculate the sample size by the formula

z = 1.96

e = 0.05

p = 0.5

On calculating we get

Sample size= 384.16

Thus, the targeted sample size for this research is taken as 385 approx.

# CHAPTER-4

# RESULTS OF DATA COLLECTED

In this chapter we discussed about survey results carried in the Gurugram city around the Rapid Metro Rail of Gurugram, three types of survey format were prepared i.e. for commuters using rapid metro, for commuters who were not using rapid metro and rapid metro inventory survey to know the facilities and information of the privately built metro stations.

## 4.1 RAPID METRO USER SURVEY

Metro commuter surveys were conducted in and around the rapid metro station to know the commuter's perception for the privately owned & built metro, approximately 401 rapid metro users were interviewed as per the commuter-based questionnaires between 26th February 2019 and 27th March 2019 and following results were observed.

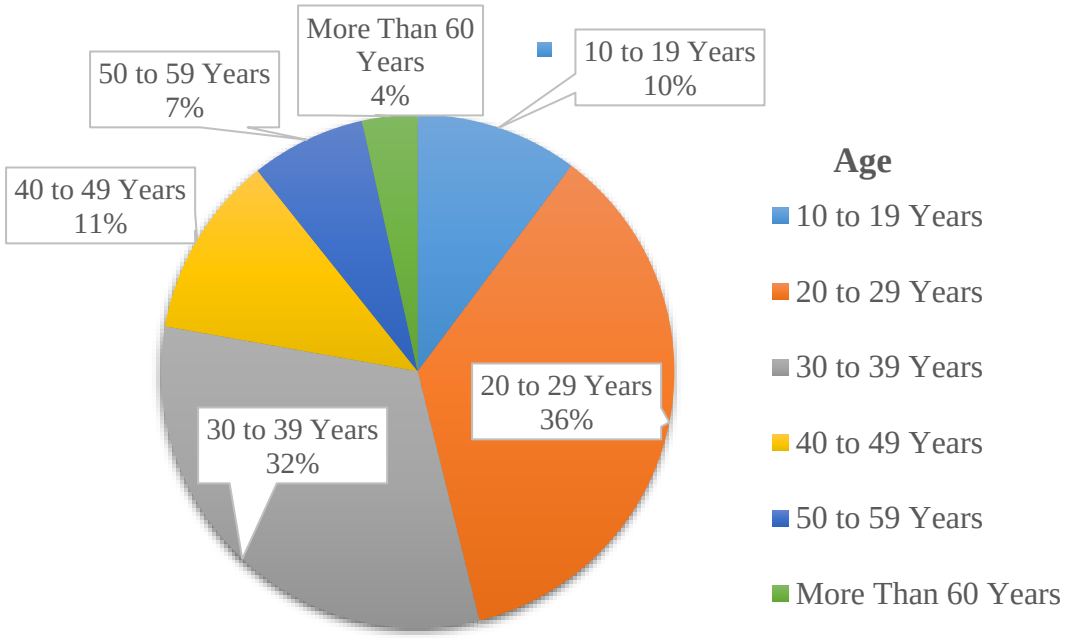



**Fig: 4.1 Age Distribution**

One of the most crucial data for metro user are their age and gender distribution, from the survey its been found that out of 401 commuters interview maximum number of people are

of the age group 20 to 29 years (36%) and 32 to 39 years (32%) (Fig: 4.1), which clearly represent the metro is being used by young and working class generation for their daily commute to different part of the city, While talking for gender distribution (Fig: 4.2), represents that approximately there is equal number of male and female distribution for the metro users.

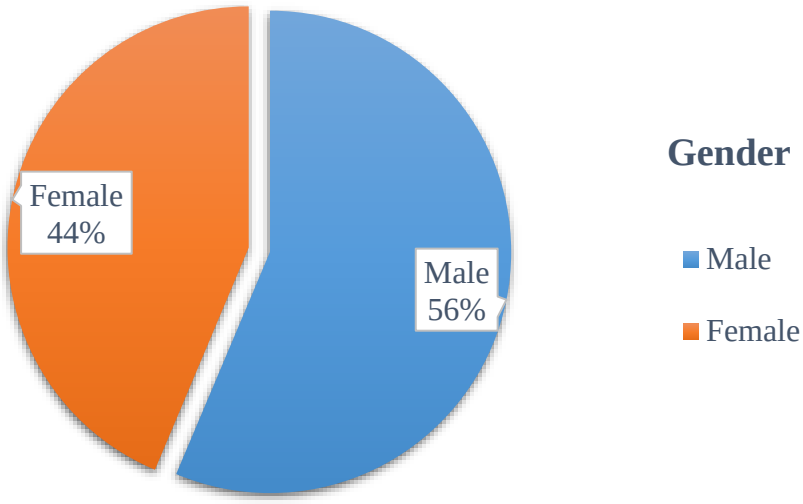



**Fig: 4.2 Gender Distribution**

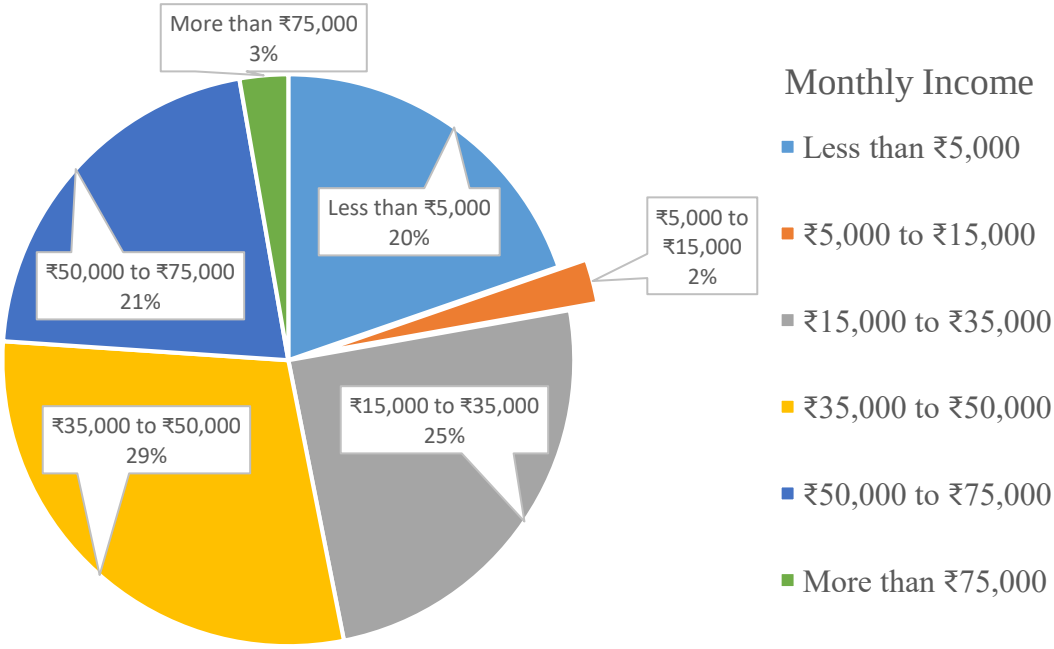



**Fig: 4.3 Monthly Income**

Income plays one of the important role as a mode choice depends upon the affordability beyond the comfort, it could be observed (Fig: 4.3) that there is a drastic fall in commuters

who has a monthly income ₹5,000/- to ₹15,000/- per month while for income groups of ₹15,000/- to ₹35,000/- and ₹35,000/- to ₹50,000/- generally represents the young working class and also explains that such a good share in rapid metro transit is due to affordability for better comfort, ease and no access to their personal mode of transit.

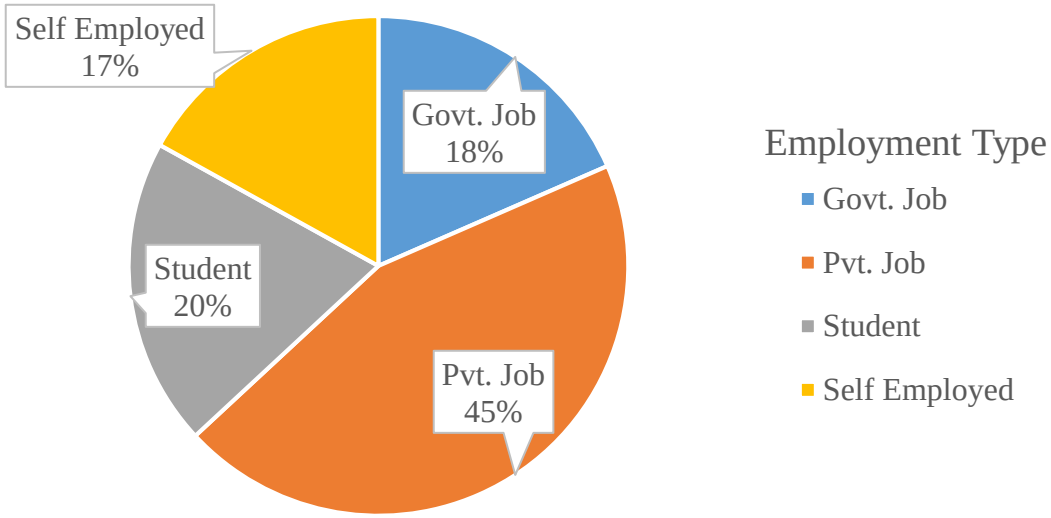



**Fig: 4.4 Distribution of Commuters on the basis of Employment**

Gurugram being a millennium city having major contribution in IT sector as rapid metro corridor is surrounded with a lot of office and commercial spaces hence metro transit user (Fig: 4.4) presents maximum number (70%) of people using transit system for office and work related purpose as 45% of the 401 surveyed commuters are working in Pvt. Sector firms (Fig:4.4,).

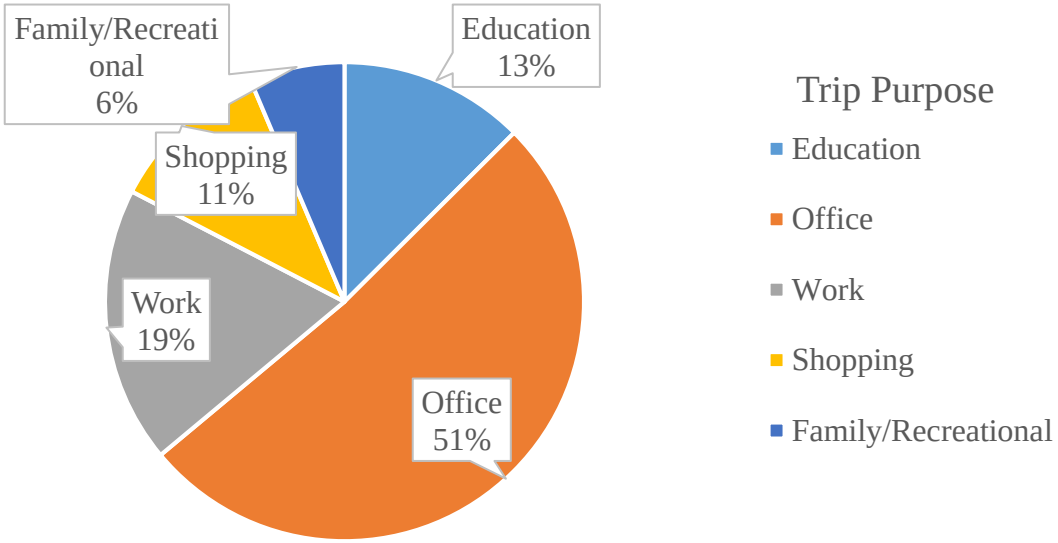



**Fig: 4.5 Metro Commuters purpose of trip**

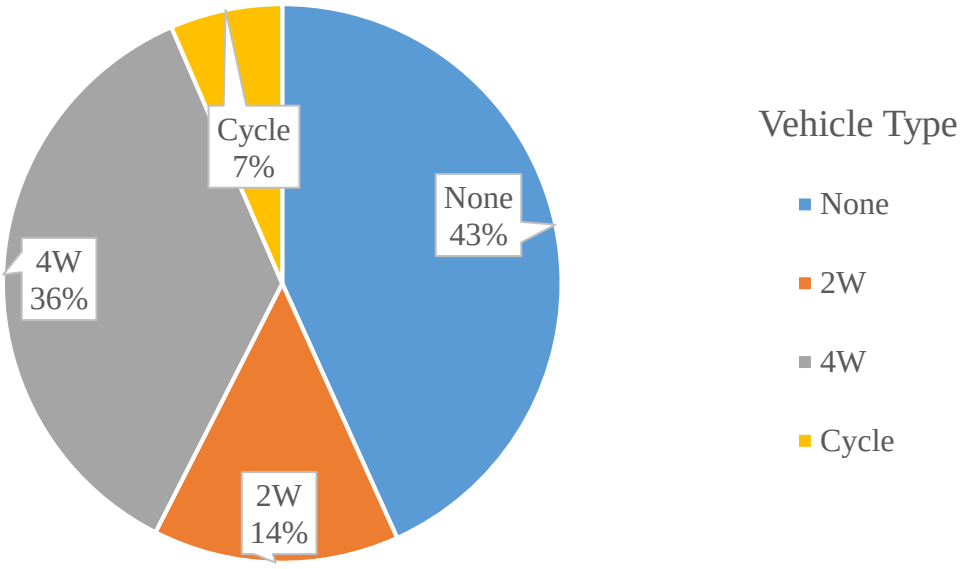



**Fig: 4.6 Metro user vehicle ownership**

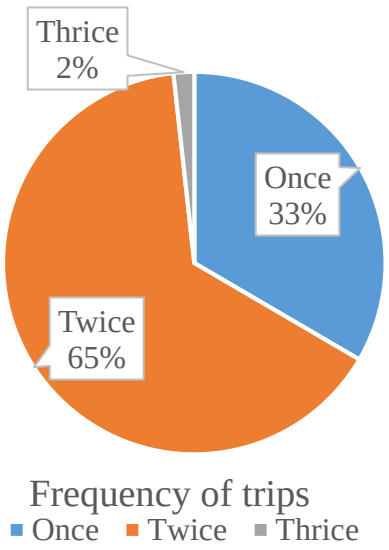



**Fig: 4.7 Daily Commuter frequency**

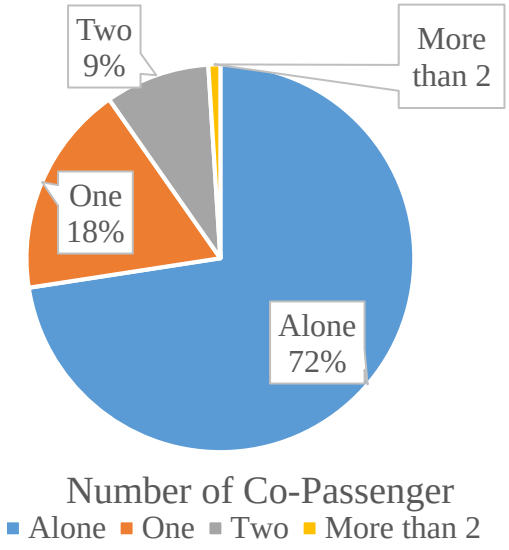



**Fig: 4.8 Co-Passenger Count**

Gurugram is a developing city, have mix class of people residing and working near the corridor of rapid metro, Fig : 4.5 clearly presents that most of the young generation don't have any vehicle ownership such that their frequency of trips (Fig:4.6) proves to and fro ridership with rapid metro from their home to office location, as most of the population of developing city are diversely settled and have different egress location, hence most (72%) of the commuter travel alone in the metro.

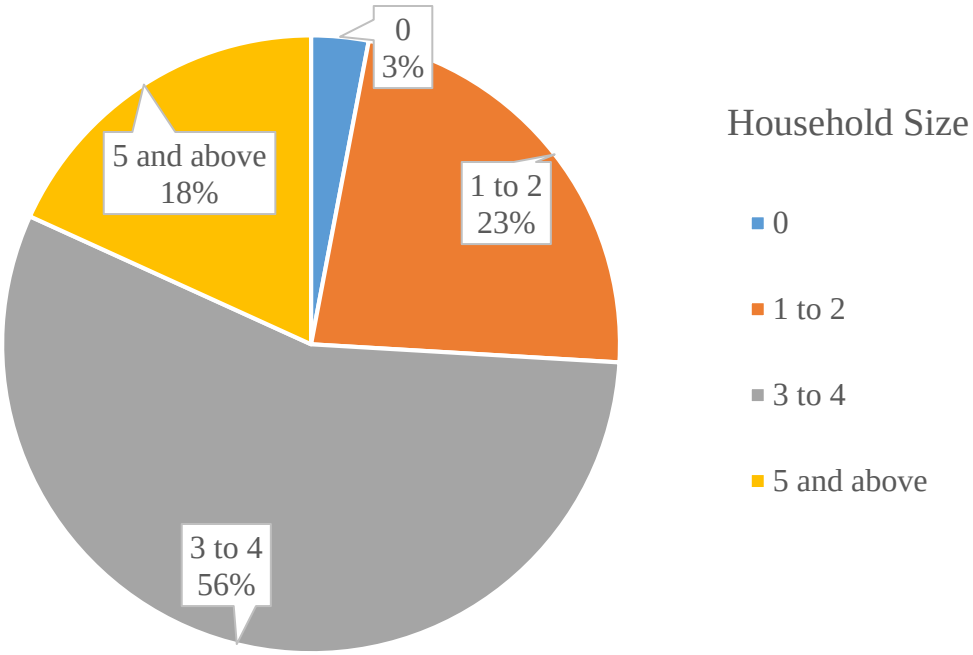



**Fig: 4.9 Commuters Household Size**

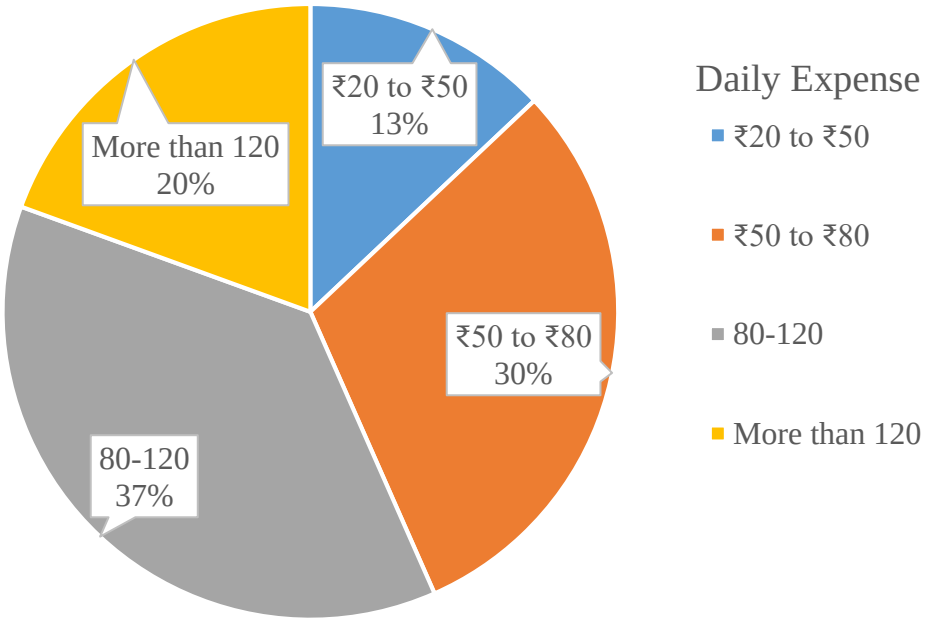



**Fig: 4.10 Daily Travel Expense by Metro User**

Rapid metro is found to have an expensive fare structure in comparison with Delhi Metro, with a minimum fare of ₹20 and maximum up to ₹35 on Rapid Metro corridor and separate fare is added for Delhi Metro (as per the fare structure of DMRC) if interchange of station is done, as Rapid metro has 12% of commuters using Share Auto (Diesel operated, Battery operated) after highest modal share as walking (71% approx..) (Fig: 4.8) as access or egress

mode, hence as the share auto cost a minimum of ₹ 10 for a approximate distance of 1 to 2 KM hence the daily total commute expenditure of about ₹50 to ₹80 of 30% of the metro user who are either using walk as a access or egress mode while share auto on the other side or both.

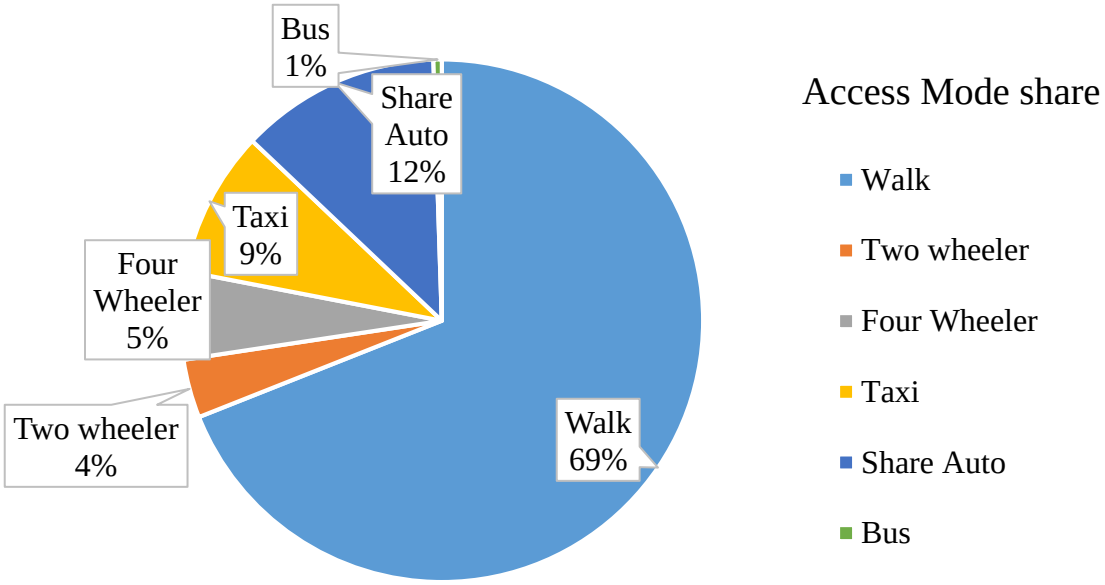



**Fig: 4.11 Access mode share to metro station**

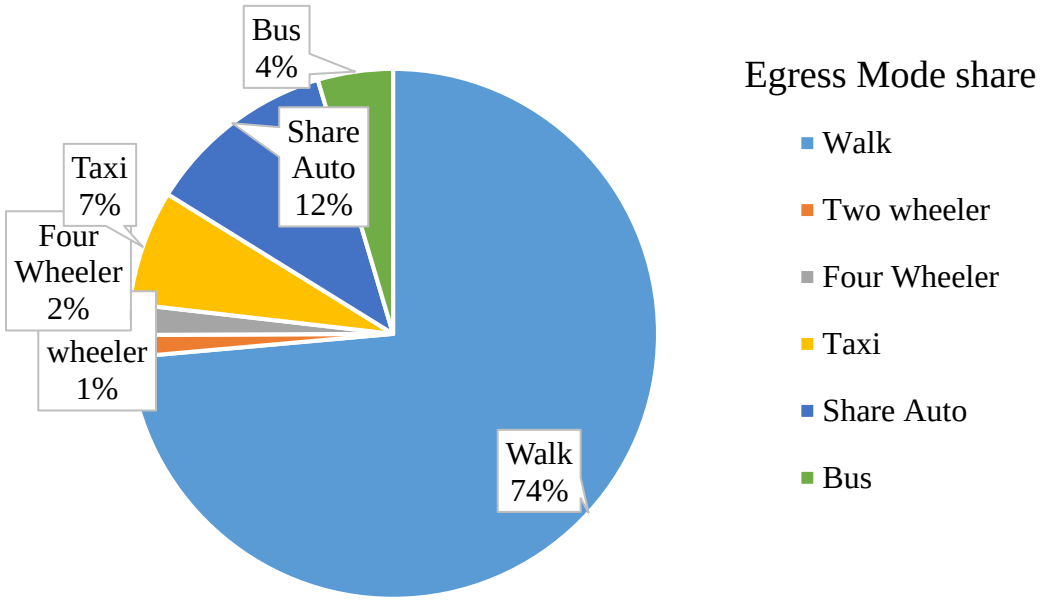



**Fig: 4.12 Egress mode share from metro station**

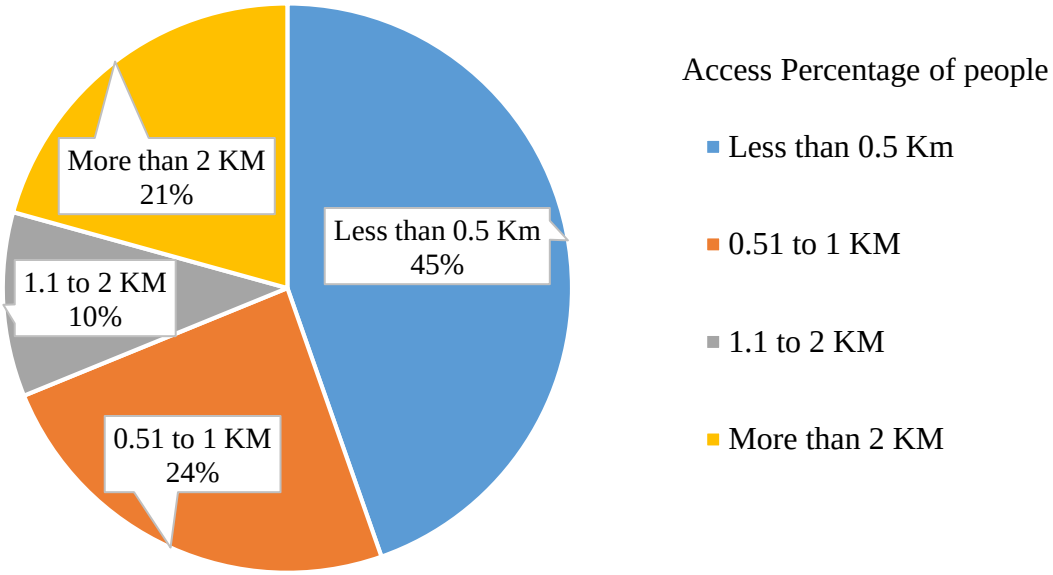



**Fig: 4.13 Access distance to metro station**

On Comparing the results of access and egress distance's (Fig: 4.10 & Fig:4.11), with Access and Egress mode adopted (Fig:4.8 & Fig:4.9) to and from metro station, it can be understood approximately 69% and 74% prefer walking to and from metro station as 40% of the access and egress locations are within the radial distance 0.5 KM, since the Gurugram metro stations are located close to the cybercity and educational institute hence commuters preferred walking wile accessing their desired destination.

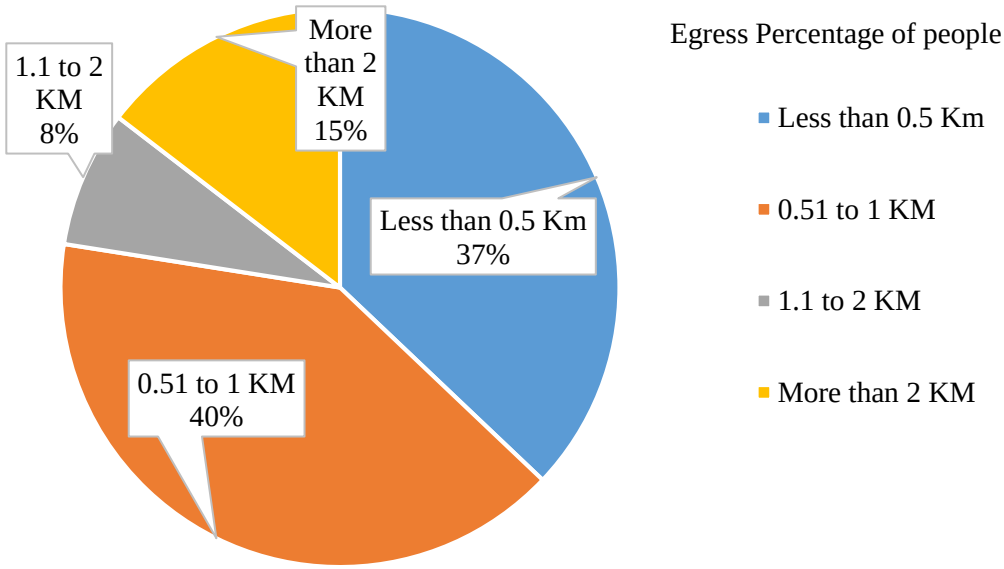



**Fig: 4.14 Egress distance from metro station**

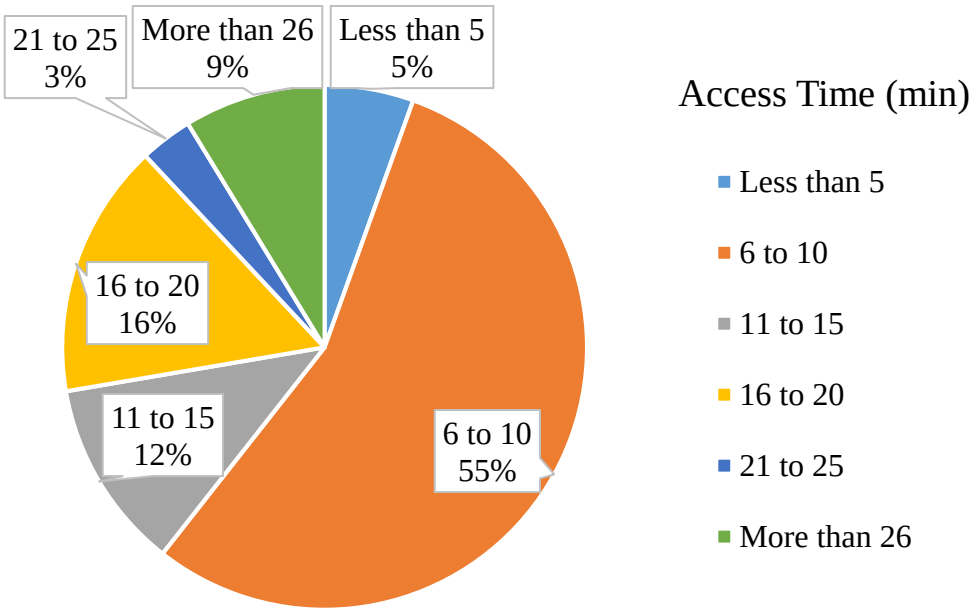



**Fig: 4.15 Access time for metro station**

Fig: 4.12 & 4.13, explains the time taken by the commuters in reaching to access & egress location as 70% of the user's (Fig:4.8 & Fig:4.9) adopted walk as favarable mode for short distance upto 1 km, Hence time taken by them in walking of about 5 to 10 mins (Fig: 4.12 & Fig: 4.13), proves to be justified

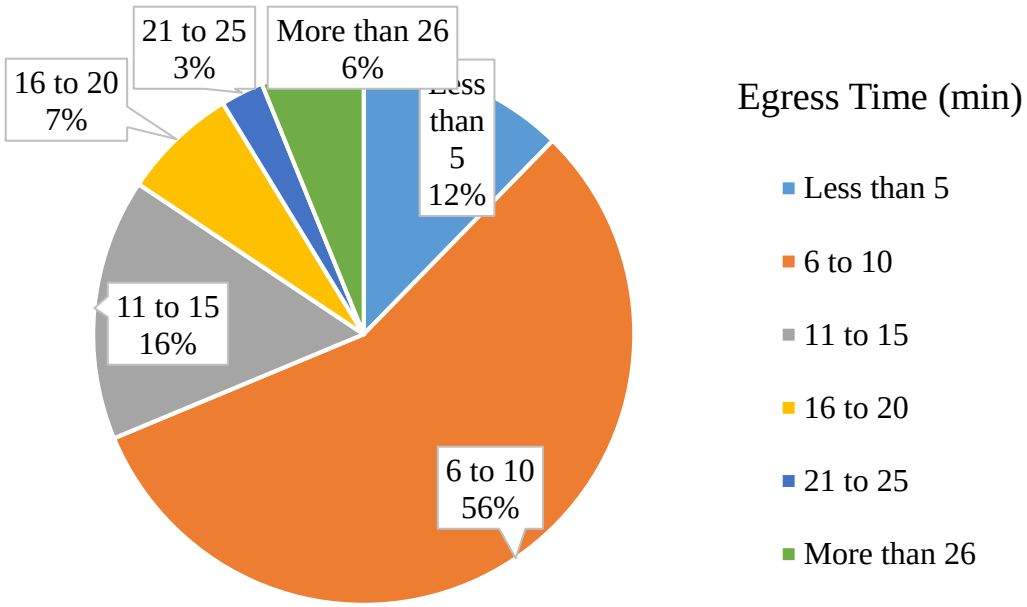



**Fig: 4.16 Egress time from metro station**

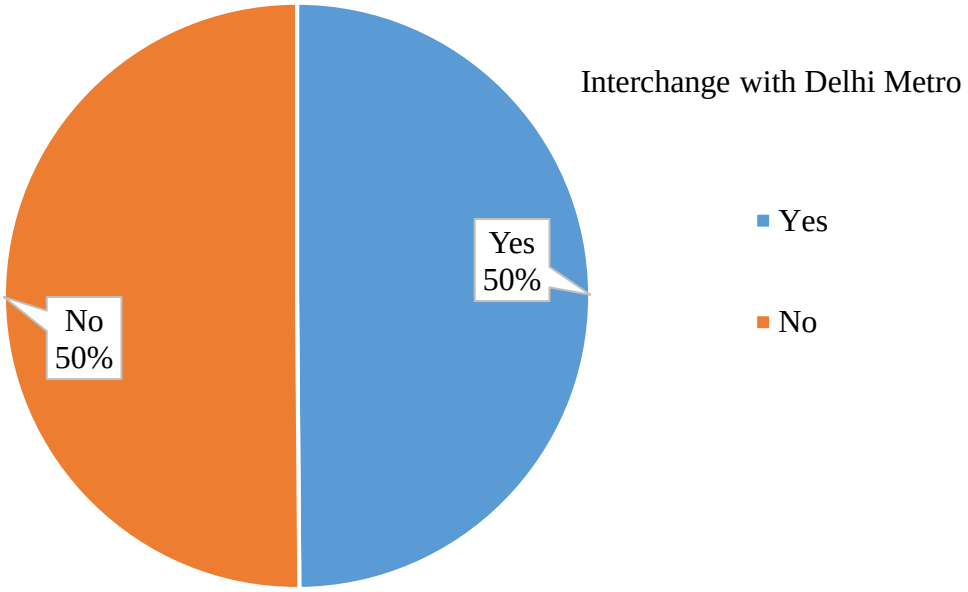



**Fig: 4.17 Commuters interchanging with Rapid Metro**

It's been observed on comparison Fig: 4.14 with Fig. 4.7, that approximately 70% of the commuters are using walking mode as access or egress so the expenditure on daily commute should be within the expense bracket of ₹20 to ₹50 which accounts to 13% of the metro users and is relatively low but here the conflicting issue of the different fare price standards of DMRC & RMGL arises approximately 50% of rapid metro user are interchanging at Sikanderpur metro station due to which a daily expenditure share of commuter rises by ₹20 even if they visit one single station of Rapid metro beyond the interchanging point.

## 4.2 RAPID METRO NON-USER SURVEY

Non-Metro user survey was conducted at or in different locations of the Rapid metro corridor, some of the location which were selected in an about a radius of 2.5 KM which can turn out to be an easy catchment area location for studying the last mile connectivity for rapid metro corridor, Table 4.1 Explains the feedback of the 323 Non-Metro users for not using the rapid metro, feedback from different mode user such as private car, private two wheeler, Public share auto, taxi, Gurugaman bus and any other mode user were grouped with several reason in respect of reason for not using the rapid metro.

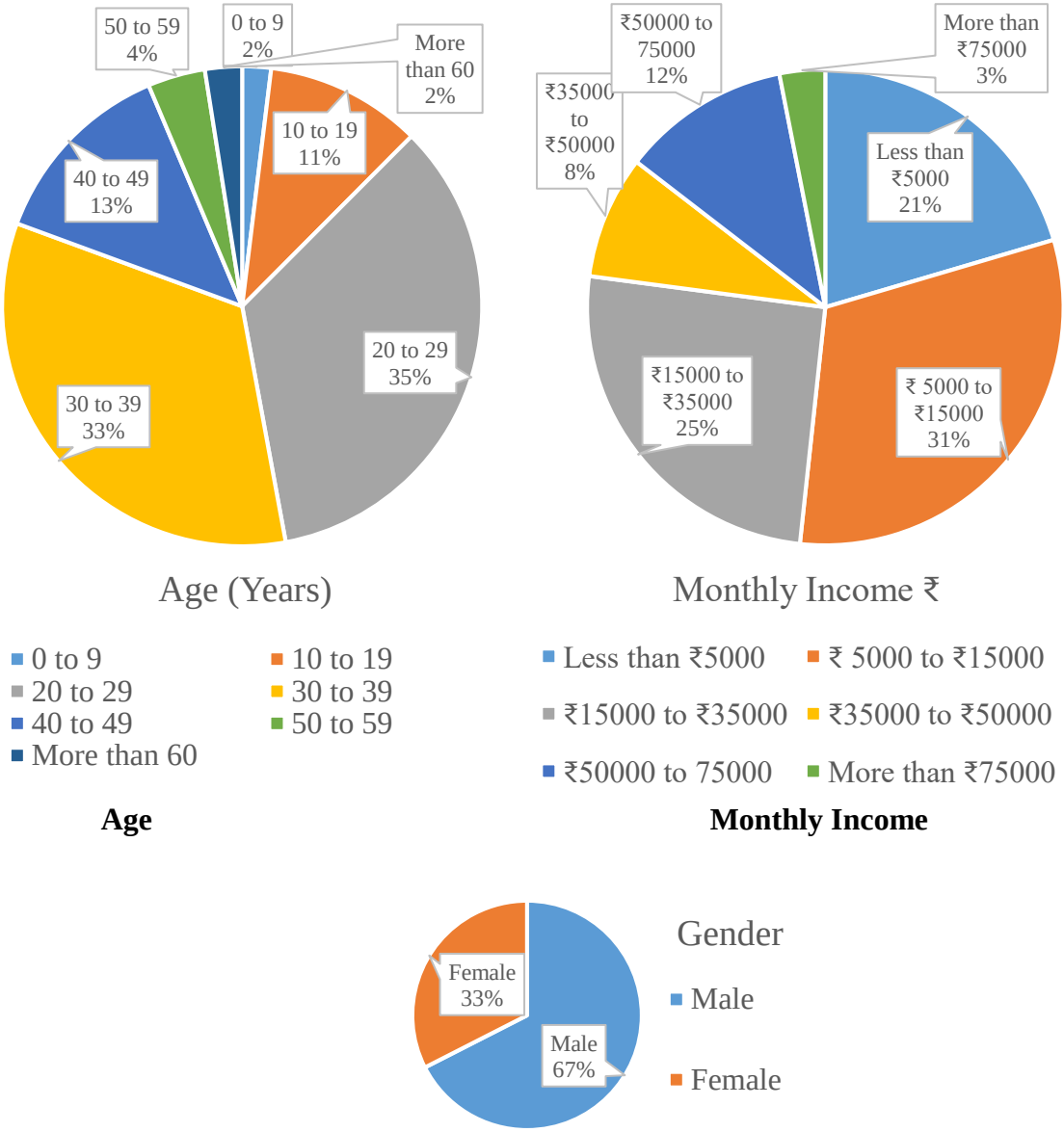
**Table: 4.1 Non-Metro User Survey Results**

| Reason for not using Rapid Metro | Mode choice | Percentage of Commuters | Reason |
|---|---|---|---|
| Cost/Expensive | Car User | 31% | • Access cost up to station and overall journey is more than the cost will be on personal mode<br>• Have allotted parking space in office<br>• Do daily car pool with office colleague hence cost is almost equal to public transport |
| | 2W User | 22% | • Access cost up to station and overall journey is more than the cost will be on personal mode |
| | Taxi/Auto User | 20% | • Cost of Taxi and over all journey is almost equivalent |
| | Share Auto | 72% | • Very less cost (50% fare difference) |
| | Gurugaman Bus User | 75% | • Very less cost (40% fare difference) |
| | Other Pvt. Bus User | 88% | • Very less cost (75% fare difference) |
| Egress location Doesn't lie around the Rapid Metro corridor | Car User | 87% | • Comfortable with personal car<br>• No need to walk |
| | 2W User | 93% | • Comfortable with personal vehicle and metro don't connect to location directly.<br>• Have to walk very less |
| | Taxi/Auto User | 45% | • Unnecessary struggle is avoided irrespective of the cost. |
| | Share Auto | 20% | • Auto connects directly to location<br>• Stops were ever required. |
| | Gurugaman Bus User | 10% | • 1.Connects directly to egress location |
| | Other Pvt. Bus User | 12% | • Stops were ever required |
| No parking Space at Access metro Station | Car User | 90% | • Have allotted parking space in office and total cost with bike is much less than on public transport.<br>• Comfortable with personal car<br>• No need to walk |
| | 2W User | 95% | • Have allotted parking space in office and total cost with bike is much less than on public transport.<br>• Comfortable with personal mode<br>• No need to walk |
| | Taxi/Auto User | 18% | • 1.Very less cost (75% fare difference)<br>• 2. Have to walk very less |
| | Share Auto | 2% | • Auto drops me to the desired location |

| | | | |
|---|---|---|---|
| | Gurugaman Bus User | 0% | • No reason |
| | Other Pvt. Bus User | 0% | • No Reason |
| Transferring is time consuming | Car User | 73% | • Waste of time in checking in metro & waiting for metro |
| | 2W User | 89% | • Waste of time in checking in metro & waiting for metro |
| | Taxi/Auto User | 82% | • Waste of time in checking in metro & waiting for metro |
| | Share Auto | 35% | • Waste of time in checking in metro & waiting for metro |
| | Gurugaman Bus User | 18% | • Avoid rising so many stair's<br>• Wait time for bus and metro almost equal |
| | Other Pvt. Bus User | 7% | • Don't want walk upto station as us is available on my door |
| Avoid Security Checks | Car User | 5% | • No comments |
| | 2W User | 7% | • No comments |
| | Taxi/Auto User | 11% | • No Comments |
| | Share Auto | 62% | • Security don't allow our tool boxes and large baggage<br>• Pan, Gutka, cigarette liters are removed so avoid |
| | Gurugaman Bus User | 38% | • Security don't allow our tool boxes and large baggage<br>• Pan, Gutka, cigarette liters are removed so avoid |
| | Other Pvt. Bus User | 57% | • Security don't allow our tool boxes and large baggage<br>• Pan, Gutka, cigarette liters are removed so avoid |
| Operating Time not adequate (also not in alignment with Delhi Metro ) | Car User | 0 % | • N.A. |
| | 2W User | 0 % | • N.A. |
| | Taxi/Auto User | 22 % | • Metro don't operate after 10 PM |
| | Share Auto | 8 % | • Metro don't operate after 10 PM |
| | Gurugaman Bus User | 5 % | • Metro don't operate after 10 PM |
| | Other Pvt. Bus User | 14 % | • Metro don't operate after 10 PM |
| Not comfortable | Car User | 66 % | • Have to walk a lot |
| | 2W User | 32 % | • Don't want to walk |
| | Taxi/Auto User | 10 % | • No comments |
| | Share Auto | 0 % | • N.A. |
| | Gurugaman Bus User | 0 % | • N.A. |
| | Other Pvt. Bus User | 0 % | • N.A. |
| Unsafe | Car User | 18 % | • There is no ladies specific coach |
| | 2W User | 7 % | • No Comments |

| | | | |
|---|---|---|---|
| | Taxi/Auto User | 10 % | • Unsafe in nights |
| | Share Auto | 0 % | • N.A. |
| | Gurugaman Bus User | 0 % | • N.A. |
| | Other Pvt. Bus User | 0 % | • N.A. |
| Less availability of modes from the station to egress location | Car User | 67% | • Avoid walking |
| | 2W User | 81% | • Avoid walking |
| | Taxi/Auto User | 45% | • Overall i prefer taxi |
| | Share Auto | 5% | • No comments |
| | Gurugaman Bus User | 3% | • No comments |
| | Other Pvt. Bus User | 0% | • No comments |
| Access modes to station are far | Car User | 93% | • Avoid walking |
| | 2W User | 91% | • Avoid walking |
| | Taxi/Auto User | 90% | • Cost component increases |
| | Share Auto | 62% | • Cost component increases |
| | Gurugaman Bus User | 40% | • Cost component increases |
| | Other Pvt. Bus User | 43% | • Cost component increases |
| Cheaper alternative, better than metro | Car User | 45% | • Hardly any cost difference rather more efforts |
| | 2W User | 82% | • Hardly any cost difference rather more efforts |
| | Taxi/Auto User | 23% | • It's a struggle in accessing station |
| | Share Auto | 96% | • It's a struggle in accessing station |
| | Gurugaman Bus User | 65% | • It's a struggle in accessing station |
| | Other Pvt. Bus User | 78% | • It's a struggle in accessing station |
| Overcrowded metro | Car User | 10% | • Avoid peak hour rush |
| | 2W User | 16% | • Avoid peak hour rush |
| | Taxi/Auto User | 30% | • Avoid peak hour rush |
| | Share Auto | 0% | • N.A. |
| | Gurugaman Bus User | 0% | • N.A. |
| | Other Pvt. Bus User | 0% | • N.A. |

### 4.2.1 Demographic Details of Non-Metro User




**Age**

**Monthly Income**

**Gender**

**Fig: 4.18 Demographic Survey of Non-Metro commuters**

From Fig: 4.15, being a male interviewer female interview was difficult as women avoided to stop and respond to stranger on open streets, still it was observed 33% female potential commuter avoided to commute with rapid metro, due to many multiple reasons mentioned in Table 4.1,

## 4.3 RESULTS OF INVENTORY SURVEY FOR METRO STATIONS

An inventory survey was carried out for all 11 rapid metro station and also for 5 Gurugram Region Delhi metro stations, so as to understand the demographics of all the metro stations used for transit and improve the last mile connectivity for the millennium city.

### 4.3.1 Pedestrian Access facilities

Pedestrian access facilities were found to be in a very good and clean condition at all the rapid metro station, the minimum side walk thickness was observed as 3.50 m at highly congested station's like belvedere towers, Indusland cyber city and Sikanderpur metro station while at other station it was more than 4.50 m in width and with minimum side walk height of 200 mm.

**Fig: 4.19 Pedestrian access facilities at Belvedere Towers**


**Fig: 4.20 Ramps & side walk with guard rails at Sector-43 Station**

Rapid metro stations were found to be very clean and equipped with all the essential pedestrian access infrastructure, details mentioned in table 4.1. Elevators and Escalators are provided on all the station but the escalators are for only pedestrians moving upside while normal staircase is provided for commuters descending from the metro station.

### 4.3.2 Access facilities

Rapid metro station's also act as a foot over bridges for crossing the main carriage way (Golf Corse Road), Fig: 4.10, shows the foot over bridge on Sikanderpur metro station.

**Fig: 4.21 Foot over bridge on Sikanderpur Metro Station**

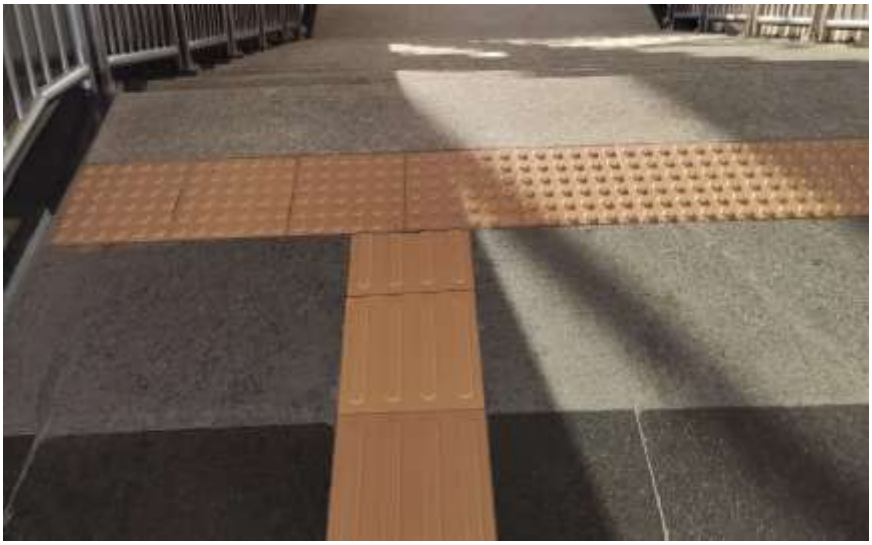


**Fig: 4.22 Adequate floor pattern or braille signage for blind people at metro station**

**Table: 4.2 Pedestrian Access facilities**

| Station location | Sidewalks present in the area? | If yes, what is the width of the side walk? (m) | How many people use the side walk in a 5 min interval | Does it happen that people abandon the sidewalk and walk on roads? | Is the side walk clean? | Is the side walk mounted with guard rails? | Is the sidewalk mounted with unnecessary obstructions? | What is the height of the side walk? | Are the pedestrian paths broken? |
|---|---|---|---|---|---|---|---|---|---|
| | PEDESTRIAN ACCESS FACILITIES | | | | | | | | |
| Sector 55-56 | Yes | > 4.50 | 30 - 50 | Yes | Yes | Yes | No | 0.35 | No |
| Sector-54 Chowk | Yes | > 4.00 | 30 - 50 | Yes | No | Yes | No | 0.35 | No |
| Sector 53-54 | Yes | 3.50 | > 50 | Yes | No | Yes | No | 0.35 | No |
| Sector-43 | Yes | 3.50 | 10 – 30 | Yes | Yes | Yes | No | 0.2 | No |
| DLF Phase-1 | Yes | > 4.50 | 10 – 30 | Yes | Yes | Yes | No | 0.2 | No |
| Sikanderpur | Yes | > 2.00 | > 50 | Yes | No | Yes | No | 0.2 | No |
| DLF Phase-2 | Yes | > 4.50 | 30 - 50 | Yes | Yes | Yes | No | 0.2 | No |
| Belvedere Tower | Yes | 3.50 | 30 - 50 | Yes | Yes | Yes | No | 0.2 | No |
| Indusland Cyber City | Yes | 3.50 | > 50 | Yes | Yes | Yes | No | 0.3 | No |
| Moulsari Avenue | Yes | 3.50 | 10 – 30 | Yes | Yes | Yes | No | 0.2 | No |
| DLF Phase-3 | Yes | > 6.00 | > 50 | Yes | Yes | Yes | No | 0.2 | No |
| Sector-55-56 | Yes | 3.50 | 30 - 50 | Yes | Yes | Yes | No | 0.35 | No |

**Table: 4.3 Access facilities to rapid metro station**

| Station Location | Are proper lightening facilities available on pedestrian sidewalks? | Are there skywalks on the station? | Is there pedestrian foot over bridges (F.O.B) present in the station premises? | Are ramps / elevators / escalators provided? | Are there how many hoardings/ advertisement boards? | Are proper signage provided? | Are there security arrange ments? | Is there any provision for the luggage trolley? |
|---|---|---|---|---|---|---|---|---|
| | ACCESS FACILITIES | | | | | | | |
| Sector 55-56 | Yes | No | Yes | Ramps & elevator provided, but Escalators only upside direction | Yes, More than 10 | Yes | Yes | No |
| Sector 54 Chowk | Yes | No | Yes | Ramps & elevator provided, but Escalators only upside direction | Yes, More than 10 | Yes | Yes | No |
| Sector 53-54 | Yes | No | Yes | Ramps & elevator provided, but Escalators only upside direction | Yes, More than 10 | Yes | Yes | No |
| Sector-43 | Yes | No | Yes | Ramps & elevator provided, but Escalators only upside direction | Yes, More than 10 | Yes | Yes | No |
| Phase-1 | Yes | No | Yes | Ramps & elevator provided, but Escalators only upside direction | Yes, More than 10 | Yes | Yes | No |
| Sikanderpur | Yes | Yes | Yes | Ramps & elevator provided, but Escalators only upside direction | Yes, More than 10 | Yes | Yes | No |
| Phase-2 | Yes | No | No | Ramps & elevator provided, but Escalators only upside direction | Yes, More than 10 | Yes | Yes | No |
| Belvedere Tower | Yes | No | No | Ramps & elevator provided, but Escalators only upside direction | Yes, More than 10 | Yes | Yes | No |
| Indusland Cyber City | Yes | Yes | No | Ramps & elevator provided, but Escalators only upside direction | Yes, More than 10 | Yes | Yes | No |
| Moulsari Avenue | Yes | No | No | Ramps & elevator provided, but Escalators only upside direction | Yes, More than 10 | Yes | Yes | No |
| Phase-3 | Yes | No | No | Ramps & elevator provided, but Escalators only upside direction | Yes, More than 10 | Yes | Yes | No |

| Station location | What type of facilitates are in use for announcing travel times / arrivals / departures? | | | | Are there doorways to the access areas for disables users? | Is there an information / query window at the station? | Is the flooring proper to walk upon? | Can elderly easily move around in the station premises? | Are ticket counters easily accessible to all users including disabled? | Is there adequate floor pattern or braille signage for blind people? |
|---|---|---|---|---|---|---|---|---|---|---|
| | Manual Announcement | Recorded Announcement | VMS Board | Scrolling Morquee | | | | | | |
| | ACCESS FACILITIES | | | | | | | | | |
| Sector 55-56 | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Sector 54 Chowk | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Sector 53-54 | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Sector-43 | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Phase-1 | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Sikander pur | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Phase-2 | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Belvedere Tower | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Induslan d Cyber City | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Moulsari Avenue | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Phase-3 | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

**Table: 4.4 Facility for cyclists**

| Station location | Are there cycle tracks provided separately ? | If yes what is the width of the cycle track? | Are any signage provided for bicycle users? | How many people use bicycles for an interval of 5 minutes? | Do the advertisement boards cause any threat to the bicycle users? | Is there any bicycle parking facility available? | If a separate cycle track is present, how many lanes it has? | Are cycle tracks present on both sides of the station for access and egress? | What is the width of one lane? | Are clear road markings present for cycle tracks on the carriageway of intersections? |
|---|---|---|---|---|---|---|---|---|---|---|
| | FACILITIES FOR CYCLISTS | | | | | | | | | |
| Sector 55-56 | No | N A | No | 0 – 10 | No | No | No | No | N A | No |
| Sector 54 Chowk | No | N A | No | 10 – 20 | No | No | No | No | N A | No |
| Sector 53-54 | No | N A | No | 10 – 20 | No | No | No | No | N A | No |
| Sector-43 | No | N A | No | 0 – 10 | No | No | No | No | N A | No |
| Phase-1 | No | N A | No | 0 – 10 | No | No | No | No | N A | No |
| Sikanderpur | No | N A | No | 10 – 20 | No | No | No | No | N A | No |
| Phase-2 | No | N A | No | 0 – 10 | No | No | No | No | N A | No |
| Belvedere Tower | No | N A | No | 0 – 10 | No | No | No | No | N A | No |
| Indusland Cyber City | No | N A | No | 10 – 20 | No | No | No | No | N A | No |
| Moulsari Avenue | No | N A | No | 0 – 10 | No | No | No | No | N A | No |
| Phase-3 | No | N A | No | 0 – 10 | No | No | No | No | N A | No |

**Table: 4.5 Parking facilities at metro station**

| Station location | Is parking facility provided | Type of parking (underground Above ground or At-grade) | Approx. Number of parking | | | Approx. Area of parking? ($m^2$) | Is kerb parking observed? If yes, then what type it is | Is there any multi storied parking garage? | Are there any security arrangements in the parking lot? | Are there proper lightening amenities in the parking lot |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2W | 4W | Bus | | | | | |
| | PARKING FACILITIES | | | | | | | | | |
| Sector 55-56 | Not provided | N.A. | N A | N A | N A | N A | Yes, Unauthorized Parking in NO Parking zone | No | N A | N A |
| Sector 54 Chowk | Not provided | N.A | N A | N A | N A | N A | Yes, Unauthorized Parking in NO Parking zone | No | N A | N A |
| Sector 53-54 | Not provided | N.A | N A | N A | N A | N A | Yes, Unauthorized Parking in NO Parking zone | No | N A | N A |
| Sector-43 | Not provided | N.A | N A | N A | N A | N A | Yes, Unauthorized Parking in NO Parking zone | No | N A | N A |
| Phase-1 | Not provided | N.A | N A | N A | N A | N A | Yes, Unauthorized Parking in NO Parking zone | No | N A | N A |
| Sikanderpur | Yes | At-grade | 150 | 80 | 3 | 3500 | Yes, Unauthorized Parking in NO Parking zone | No | No | No |
| Phase-2 | Yes | At-grade | 200 | 350 | 0 | 4200 | No | No | Yes, CCTV | Yes |
| Belvedere Tower | Yes | At-grade | 150 | 400 | 0 | 5500 | No | No | Yes, CCTV | Yes |
| Indusland Cyber City | Not provided | N.A. | N A | N A | N A | N A | Yes, Unauthorized Parking in NO Parking zone | No | N A | N A |
| Moulsari Avenue | Not provided | N.A. | N A | N A | N A | N A | Yes, Unauthorized Parking in NO Parking zone | No | N A | N A |
| Phase-3 | Not provided | N.A. | N A | N A | N A | N A | Yes, Unauthorized Parking in NO Parking zone | No | N.A. | No |

| Station location | Is there any litter or garbage in the parking lot? | Is it a pay parking? | Is the parking managed by a community or by station? | If pay parking, how much is the fare? | | Is the parking time limited? | Is there a monthly pass system for parking? |
|---|---|---|---|---|---|---|---|
| | | | | 2W | 4W | | |
| | PARKING FACILITIES | | | | | | |
| Sector 55-56 | N A | N A | N A | N A | N A | N A | N A |
| Sector 54 Chowk | N A | N A | N A | N A | N A | N A | N A |
| Sector 53-54 | N A | N A | N A | N A | N A | N A | N A |
| Sector-43 | N A | N A | N A | N A | N A | N A | N A |
| Phase-1 | N A | N A | N A | N A | N A | N A | N A |
| Sikanderpur | Yes | Yes | N.A. | ₹20 for first 6 hours and ₹10 for each additional hour | ₹20 for first 6 hours and ₹10 for each additional hour | Yes | Yes |
| Phase-2 | No | Yes | N.A. | ₹20 for first 3 hours and ₹20 for each additional hour | ₹50 for first 3 hours and ₹50 for each additional hour | Yes | Yes |
| Belvedere Tower | No | Yes | N.A. | ₹20 for first 3 hours and ₹20 for each additional hour | ₹20 for first 3 hours and ₹20 for each additional hour | Yes | Yes |
| Indusland Cyber City | N A | N A | N A | N A | N A | N A | N A |
| Moulsari Avenue | N A | N A | N A | N A | N A | N A | N A |
| Phase-3 | N A | N A | N A | N A | N A | N A | N A |

| Station location | Is there adequate signage available for parking or no parking zones? | How much time is spent in fare collection | Is there any reserved parking for disabled people? | Are there CCTV's installed in the parking lot? |
|---|---|---|---|---|
| | PARKING FACILITIES | | | |
| Sector 55-56 | N A | N A | N A | N A |
| Sector 54 Chowk | N A | N A | N A | N A |
| Sector 53-54 | N A | N A | N A | N A |
| Sector-43 | N A | N A | N A | N A |
| Phase-1 | N A | N A | N A | N A |
| Sikanderpur | No | 1 min | No | No |
| Phase-2 | Yes | 40 sec | No | Yes |
| Belvedere Tower | Yes | 40 sec | No | Yes |
| Indusland Cyber City | N A | N A | N A | N A |
| Moulsari Avenue | N A | N A | N A | N A |
| Phase-3 | N A | N A | N A | N A |

### 4.3.3 Facilities for Cyclist

Rapid metro station was observed to be very poor for cycle infrastructure as the roads leading to were not having any cycle lanes, cycle stands. Though many rental "mobycyc" cycles were seen parked on the footpaths of Sector-54 Chowk, Sector-43, DLF Phase-1 metro station. (Details Mentioned in table 4.3)

**Fig: 4.23 Parked "Mobycyc" battery cycle at metro station**

### 4.3.4 Parking Facilities

Most of all the metro station don't have any parking facilities, only DLF Phase-2 and Belvedere Tower metro station have parking facilities for approximately more than 300 four wheelers and 150 two wheelers, parking fare charges were found to be very expensive for parking more than 3 hours, Fig 4.13

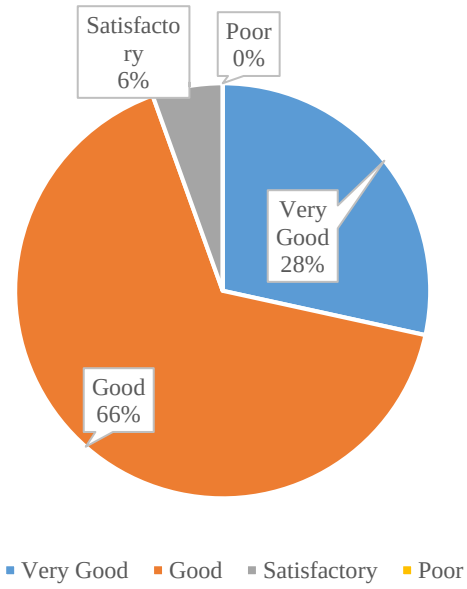
**Fig: 4.24 Parking facilities at DLF Phase-2 metro station**

Table 4.4, presents all the data regarding parking facilities, at many locations vehicles were seen parked unauthorizing waiting for fellow passengers as no waiting location were not there near the metro stations.

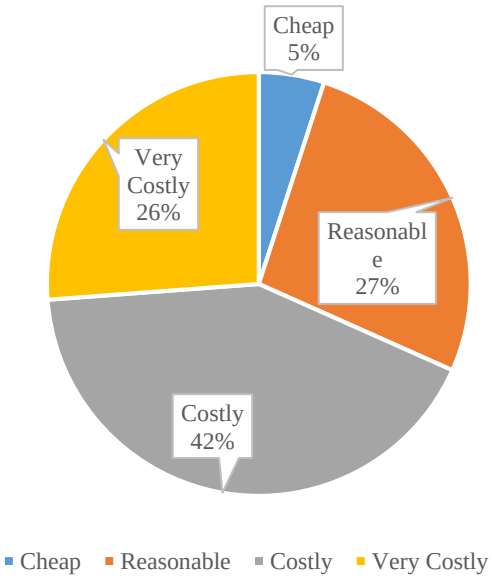
| | |
|---|---|
| DLF Phase-1<br>  | |
| Sector 42-43<br>  <br>  | • The station is a part of golf course road, one side there is residential sector-42, while on the other side there is residential Sector 43.<br>• There is a small mall cum office space adjacent to metro station due to which the footpaths are generally encroached with parked vehicle despite of the guard rails present over the footpath, hence pedestrians have to walk on the carriageway despite of presence of footpaths |
| Vivo Sector 53-54<br>  | |

| | |
|---|---|
| Sector 54 Chowk<br>  <br>  | • This is one of the prominent stations as this station is surrounded with highly occupied multistoried residential sector, 2 educational institute, 1 mall and 2 MNC building. |
| Sector 55-56<br>  | 1. Footpath's leading to station are either broken or not continues and are encroached by vendors moreover the trees and shrubs are not well trimmed such as pedestrian avoid using foot path<br>2. the bus stand cum waiting area is full of mud such that busses tend to skip the station's stop and stops the busses on the main carriageway such that the risk to passenger's increases<br>3. pedestrian's crossing are not marked with zebra crossing moreover road as divider's are encroached with high concrete barricades. |

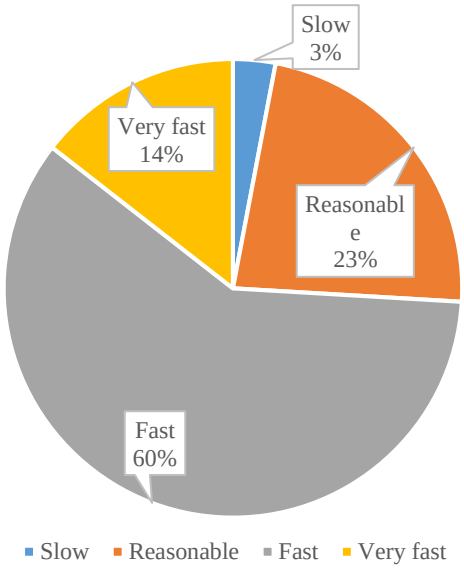
## 4.2 RESULTS OF COMMUTER PERCEPTION



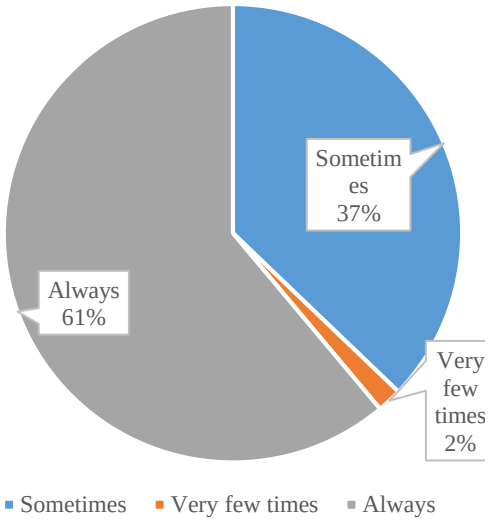

**How's the Metro Services**




**Metro travel cost**




**Speed of Metro**




**Do you get seat in metro**

**Fig: 4.25 Commuter perception results**

From the commuter perception survey the metro commuters were observed highly satisfied with the services of rapid metro services in respect speed and availability of seats in metro, but the commuters responded metro services as expensive in comparison to Delhi metro and alternate options on the same route.

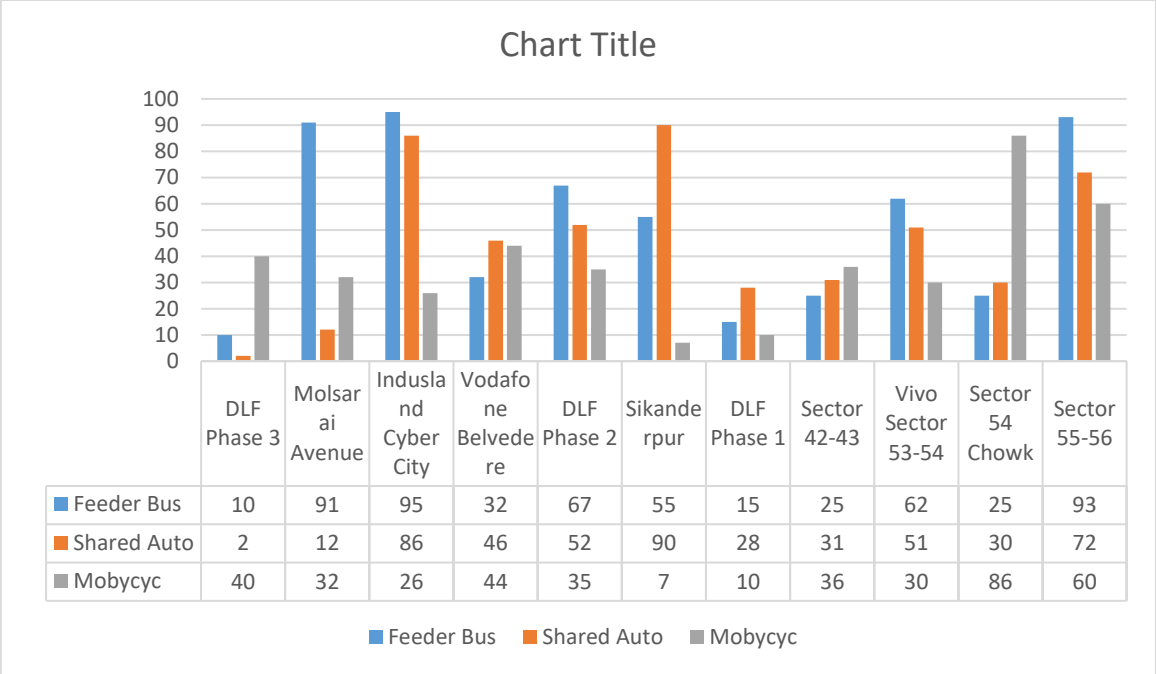



**Fig: 4.26 Mode choice for LMC by Metro user**

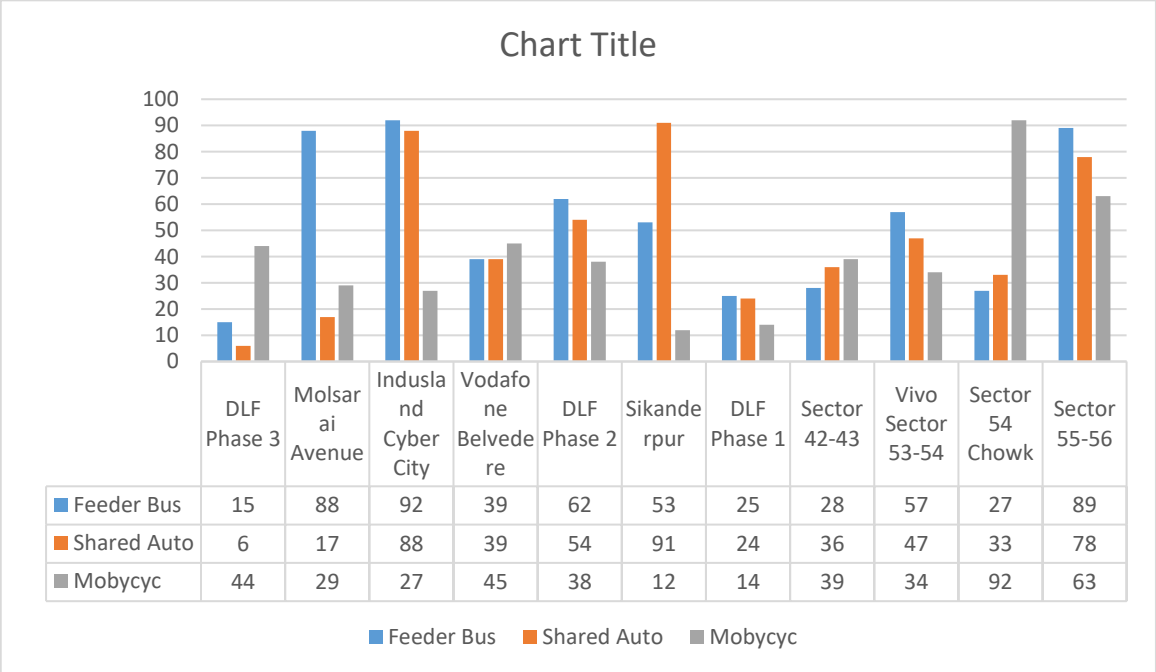



**Fig: 4.27 Mode choice for LMC by Non-Metro user**

# CHAPTER-5

## 5.1 GENERAL

Apart from providing the urban transit infrastructure, the continuous monitoring of its performance and the assessment of its effectiveness also is a significant responsibility. The urban area of Gurugram in India has been taken as a case study in this research to study the efficacy of the Last mile connectivity in an urban public transit system. The toolkit used for the purpose is Data Envelopment Analysis (DEA), which is an application of linear optimization technique and calculates the relative efficiencies of its decision-making units (DMU's) for a multitude of inputs and outputs. The study area has been chosen as Rapid Metro rail stations of the Gurugram Metro and the commuter-based questionnaire was used to collect responses regarding the demographic, travel time parameters and quality perception from the passengers and non-users. Responses were analyzed and relative rankings of the DMU's were taken out. The results revealed efficiency scores along with the inefficiency slacks for which enhancement interpretations and recommendations have been put forward.

The urban transit system in Gurugram in India is studied in a comprehensive manner in this research. The line haul mode in this transit structure is the Gurugram Rapid Rail and Gurugaman Bus and therefore, the study has been done around the Rapid Metro as the Gurugaman Bus was not operational when this study commenced. It has been recently introduced in the Urban Transit scenario of Gurugram in March 2019.

A urban transit system essentially comprises of four main elements, access leg or first mile, egress leg or last mile, line haul leg and the transfer stages. Urban transportation clearly identifies the stage -base nature of the public transport (Krygsman S. et al 2001). Now, when an individual makes a trip from origin to destination by using non-personal modes or public transportation modes, then a combination of these modes are often utilized. The vehicle exchange joint or the terminal plays a vital role in the trip. Together, the usage of two or more modes with at least one mode a conventional public transport mode in the trip

is referred to as a Urban Transit trip. The structure of an Urban trip with First and Last Mile Connectivity components is as illustrated in Figure 5.1.

The urban trip starts at the origin with a number of options for the first leg, i.e. the access part like taking up the car, two-wheeler, cycle, auto, rickshaw, bus or walking to reach the transfer station for a line haul mode like Gurugram rapid rail. For the line haul mode an extensively connected mode is usually chosen which in the case of Gurugram is the rapid rail. Once the travel in the rapid rail is concluded then comes the egress part. Here again, a variety of modes are available like walking, IPT (Intermediate Para Transit) modes, bus and in some cases a car or two-wheeler amongst the personal modes too. In most cases the last mile part has a disadvantage over the availability of personal modes at the destination end.

In the present scenario for a city like Gurugram and the limitations of funds, space etc., these may not really be of much help. Instead of increasing the number of modes, Gurugram needs to manage the current modes in congruence with each other to yield better system efficiency and patronage. Two major aspects that are to be understood before starting an evaluation or assessment study on a urban public transport system is the factors that dissuade the passengers from travelling with public transport and the factors that influence their decision to travel in the public transport system (Eluru, N. et al. 2012). The attributes like the travel time, waiting time, number of transfers, walking time, income group, gender play key roles in this selection.

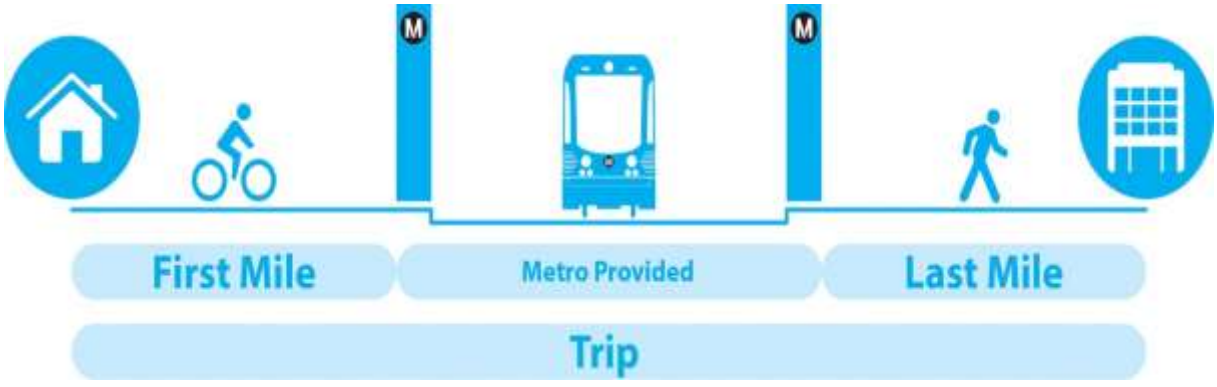



**Fig: 5.1 Structure of a Multimodal Trip showing Last Mile Component.**

## 5.2 METHODOLGY

Stations on an individual as well as corridor level have been taken for the comparative study of Gurugram metro. Figure 5.2, shows the line map of the Gurugram Rapid Metro Transit route.

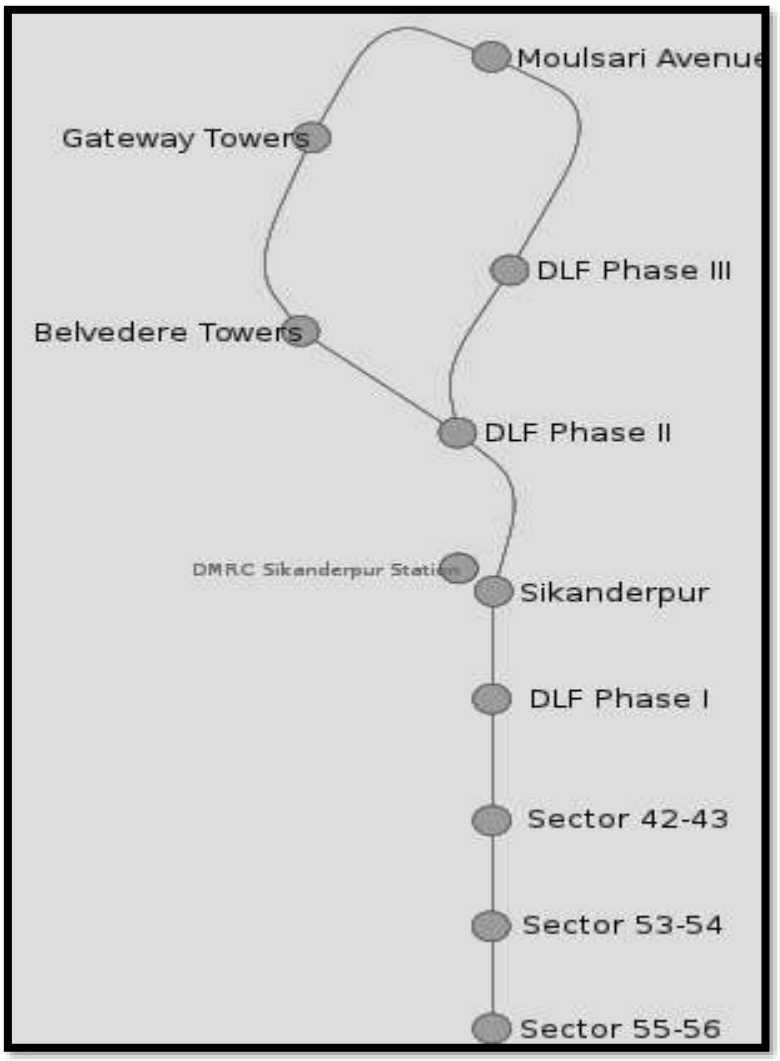



**Fig: 5.2 The Line Map of Gurugram Rapid Rail Metro Route**

The Gurugram metro has already increased the connectivity of the city. But, what about the proximity and overall interconnectivity of the area? This needed to be addressed by conducting a comprehensive evaluation of various resource units and performance indicators of the existing system and required to be compared within the system for best practices for replication in the upcoming phases. The study methodology has been shown in Figure 5.3.

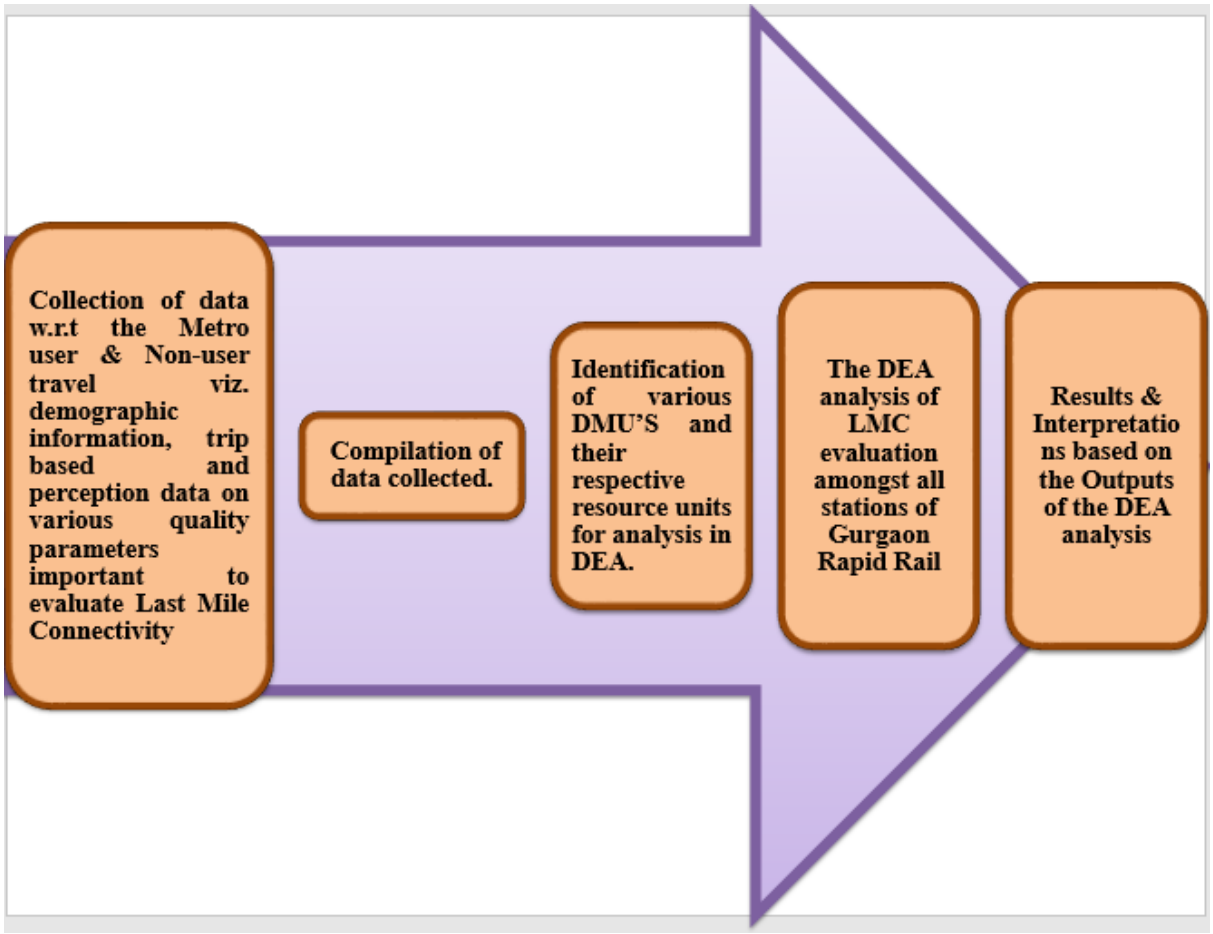



**Fig: 5.3 DEA Steps flowchart**

**Concept of DEA based Efficiency**

The DEA is based on comparing various homogeneous units of a particular system and then finding out the most efficient one from amongst them. The units compared are called decision making units or DMU's. In the subsequent sections DEA is discussed in detail.

## 5.3 EVOLUTION OF DEA

DEA model is used for computing the efficiency of a DMU relative to similar DMU's in order to evaluate a 'best practice' frontier. Farrell (1957) applied for the 1st time all the developments to calculate technical efficiency. This innovative work influenced the making of major frontier analysis technique Data Envelopment Analysis (DEA). Farrell's paper (1957), which did not suitably address mix inefficiencies, encouraged Charnes, Cooper & Rhode (CCR, 1978) to develop another frontier analysis technique called

Data Envelopment Analysis (DEA). DEA is a non-parametric benchmarking analysis (i.e. which does not practice statistical distribution) which measures efficiency by considering some of inputs & outputs. Since, many different Data Envelopment Analysis models have been introduced, some being considerably different from their original model & DEA has being a well-established show measurement technique

Data Envelopment Analysis, DEA is a performance measurement technique that uses a comparative analysis methodology. This technique was developed in 1978 by Charnes, Cooper and Rhodes (1978) in order to aid the evaluation of various organizations. (Karlaftis 2003), has utilized this toolkit to carry out efficiency analysis of transit companies. This technique can be used to assess the existing system and further enhance the service quality by identifying the gaps. It is based on the linear programming methodology. The ratios are apt for calculation of efficiency in the case of single input and output. But, for multiple inputs and/or outputs scenario the relative weights of each of the resource and performance entity need to be considered.

Data Envelopment Analysis (DEA) is defined as an "envelope" observation in order to identify a "frontier" that is used to evaluate observations representing the performances of all of the organizations or units that are to be evaluated. The DEA is utilized in all kinds of organizations that not only include business firms but also government & non-profit agencies including hospitals, military units, schools, police forces and criminal justice systems as well as regions, countries, etc.

The term "Decision Making Unit" (DMU) was therefore introduced with each such unit to be evaluated as part of a group that utilizes similar inputs to produce similar outputs. These evaluations result in a performance score that ranges between zero & unity. The key features about

DEA are:-

- Exceedingly popular management device.
- Is used to calculate the efficiency (ŋ) of a certain number of units.
- It’s an extreme point technique & it compares each and every producer with only the "best" units.
- Unit is usually called decision making unit (DMU). DEA has been used for both production and cost.

While examining or in modelling process, the urban transport systems are taken as DMUs. We adopt that there is N DMUs which uses K inputs to find M outputs. For $i^{th}$ DMU output & input are represented by the vectors $y_i$ & $x_i$ respectively.

For each DMU, an envelopment can be obtained from the Equation following linear programming problem. Where $\theta$ is a scalar & $\lambda$ is a N * 1 vector of constants. X is the input matrix (K* N). Y is the output matrix (M *N). The value of $\theta$ achieved will be an efficiency score of the $i^{th}$ DMU. It will content $\theta \leq 1$, with a value of one representing a point on the frontier & gives a technically efficient DMU.

$Min_{\theta,\lambda}$ $(\theta)$

Such that

$$-y_i + Y\ \lambda \geq 0, \qquad (1)$$
$$\theta\ x_i - X\ \lambda \geq 0,$$
$$\lambda \geq 0$$

Equation 1 assumes the CRS, when there is difference in the operations of some DMUs with optimal scale, which may effect in efficiency scores affected by the scale efficiency.

By addition of the constraint (N1 $\lambda$= 1) to the equation of CRS linear programming problem, in Equation 2.

$Min_{\theta,\lambda}$ $(\theta)$

Such that

$$-y_i + Y\ \lambda \geq 0, \qquad (2)$$
$$\theta\ x_i - X\ \lambda \geq 0,$$
$$N1\ \lambda = 1$$
$$\lambda \geq 0$$

N1 is an N X 1 vector of ones. The VRS approach forms a convex structure of interconnecting planes, which cover the data points more forcefully than that in CRS, thus provide technical efficiency scores with more or equal to those achieved by CRS model. A comprehensive literature study on the usage of DEA in Public road transport efficiency

has been done by (Sami Jarboui et al. 2012). Also,(Zhenlin et al. 2012), did a comprehensive efficiency evaluation of the Beijing Intelligent traffic management system based on super - DEA in which they used 15 inputs and 23 outputs for 10 DMU's for a macro level study correlating the influence of urban transport system, energy environment system and socioeconomic system on the urban transport indicators and the road traffic management efficiency. (Epstein and Henderson 1989), concluded that all variables that are included in the model have an equal opportunity to influence the calculated efficiency. Here DEA is advantageous over the traditional efficiency calculations.

DEA compares different Decision Making Units (DMUs), which are often the resource units for a system. The output unit is usually a performance attribute to be judged. Then, their comparative efficiencies are compared and the best practice units are identified. Also, it identifies the slacks in the resource units as well as the output units and tells the projected values for them so they can compete the best practice unit. DEA has been used in the transportation sector in India earlier also. (Saxena Punitha et al. 2010) did a study on measuring the efficiencies of Indian Public Road Transit using DEA with Input variables such as fleet size, total staff, and fuel consumption and the output parameters passenger Kilometers and seat Kilometers for 26 DMU's.

In the DEA model, the concept of efficiency is basically technical efficiency, which is the basic concept of relative efficiency that is determined through comparison with the most efficient unit.

A common measure for relative efficiency is,

$$\text{Efficiency} = \frac{\text{weighted sum of outnuts}}{\text{weighted sum of inputs}}$$

The relative efficiency (ŋ) is typically represented in the following mathematical form in Equation 1.

$$\eta_j = \frac{\Sigma_r u_r y_{rj}}{\Sigma_i v_i x_{ij}}_j \qquad (3)$$

$\eta_j$ = relative efficiency of unit j

$v_i$ = weight on input i

$u_r$ = weight on output r

$y_{rj}$ = the quantity of output r for unit j

$x_{ij}$ = the quantity of input i for unit j

j = 1, 2, 3 … n

n = number of firms

In other words, difficult to measure absolute efficiency that is evaluated according to the point, so it is measuring the degree of efficiency through comparison with the reference set i.e. DMU that has similar input & output structure.

### 5.3.1 Basic models

CCR model of Charnes, Cooper and Rhodes (1978) and BCC Model of Banker, Charnes & Cooper (1984) are applied in most DEA models. CCR model works with the assumption of constant returns to scale & the BCC model for variable returns to scale. The CCR model is used in situations where outputs increase proportionally for increase in inputs. The BCC model fits situations where outputs do not increase proportionally for increase in inputs. A CCR efficient DMU is also BCC efficient, but the opposite is not true. Steps are taken to make them efficient.

$$\text{Max } h_o = \frac{\sum_{r=1}^{s} u_r y_{rjo}}{\sum_{i=1}^{m} v_i x_{ijo}} \qquad (4)$$

Subject to

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1 \quad \text{For each unit j} \qquad (5)$$

$v_i \geq 0$, i = 1, 2, 3… m

$u_r \geq 0$ , r = 1, 2, 3 …. s

Here the h, u, x, y, v are the same as in Equation 3 & 4 and s is no. of inputs and m no. of outputs. To make it a linear program, it is converted into following form as linear programs are easier to solve. The weight restriction that is Ɛ can't be assigned zero as inputs or the outputs are not totally ignored. The objective function is maximizing the efficiency of the DMU using the weights $u_r$ and $v_i$ for the inputs and the outputs

respectively. The model determines the weights in a manner that efficiency score of the DMU considered is maximum in Equation 5 and when the same set of weights are applied to the other DMUs in the sample their efficiency score will not exceed 1 shown in Equation 6. The mathematical formulation for the process is given below.

$$\text{Max ho} = \sum_{r=1}^{s} u_r y_{rjo} \quad \text{for DMUo} \tag{5}$$

Subject to

$$\sum_{i=1}^{m} v_i x_{ijo} = 1 \tag{6}$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0 \qquad j= 1, 2, 3\ldots n$$

$$v_i \geq \varepsilon , \qquad i = 1,2,3\ldots m$$

$$u_r \geq \varepsilon , \qquad r=1,2 ,3 \ldots . s$$

n number of units with m number of inputs & s number of outputs are used here. $x_{ij}$ represents the inputs & $y_{rj}$ is the outputs of firm j.

There is slight difference between BCC & CCR models is that in BCC model there is added constraint shown in Equation 7 as follows: -

$$e\lambda = \sum_{j=1}^{n} \lambda_j = 1 \tag{7}$$

$\lambda$ , $\lambda j$ = variables that represent slacks in the constraint

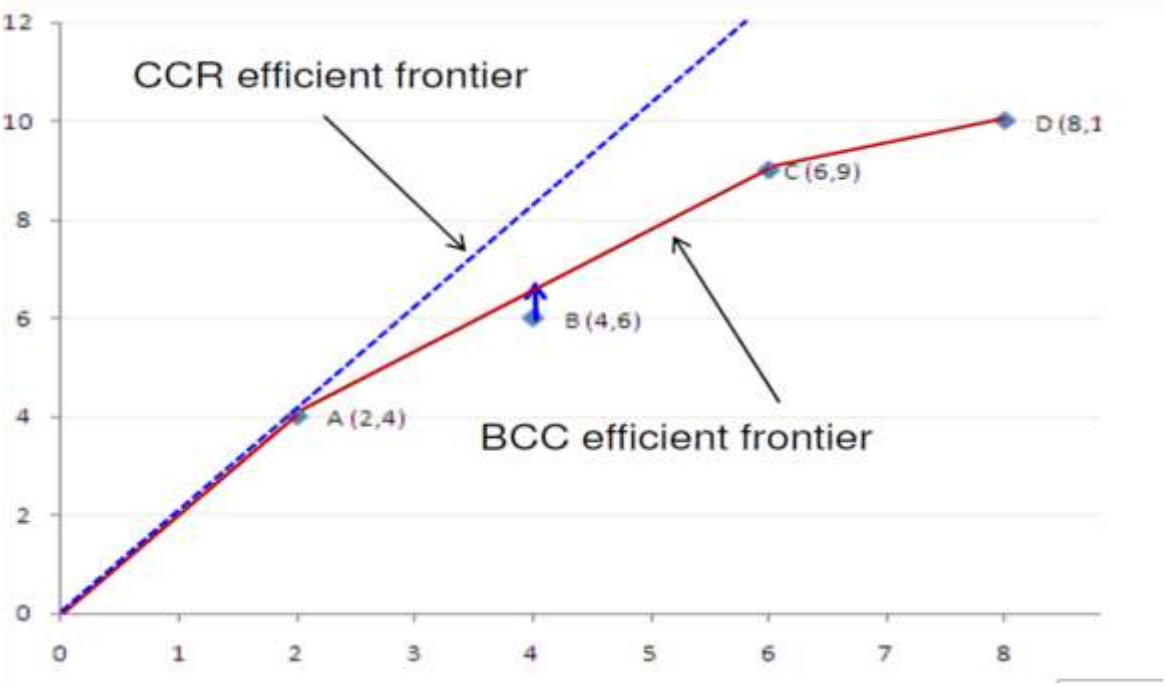



**Fig: 5.4 Comparison between CCR & BCC Efficient Frontier.**

In Figure 5.4 different lines represent the CCR and BCC efficient frontier. From this, we compare the efficiency of the different units and then inefficient units are compared with the efficient. This figure represents that the BCC model is more efficient then CCR model.

**Selection of DMUs**

Following are the two factors for the selection of DMUs for the study. Some of the qualities in the number of DMUs are: -

- The DMUs must be homogenous/similar/comparable units. They should perform the tasks & have similar objectives. The inputs and outputs describing the performance of DMUs should be same, except for changes in magnitude. For example, DEA efficiencies will not be suitable when the performance of urban roads & national highways are compared because their inputs & outputs would be very different.
- The number of DMUs to be related will depend upon an aims of the DEA study. However, for the selection of the no. of DMUs, there should be some consideration for a DEA study.

- If the number of DMUs is high, then the probability of taking high performance units that determine the efficiency frontier will also be high. A greater number of DMUs will also allow an edge over an identification of relations between inputs & outputs. However, the DEA analyst should be restrained not to increase the no. of units unnecessarily. We can't include the heterogeneous data, just for the sake of increase in number of data.
- The relation between the number of DMUs, the number of input & output is there. The number of DMUs is expected to be more than the product of number of inputs & outputs in order to differentiate effectively between efficient & inefficient DMUs.

**Advantages of DEA**

Following are some advantages of DEA which makes DEA very efficient in the present day.

- *Provides a measure of performance :* It does all the analysis and informs the decision makers about the possibly conflicting indicators. DEA offers a summary measure of performance that unites all the appropriate indicators.
- *Eliminates Peer Grouping :* DEA can take into account "background conditions" such as demographic characteristics. Although there is some grouping is still required for the analysis of the input variables to differ significantly, basically it eliminates large grouping.
- *Uses Unit less Variables :* There is no need to convert different units for input & output variables into a common unit, since DEA is nonparametric & it is not necessary to know all the form of the production function.
- *Compares Individual Agencies to the Best-Practice Agencies:* Unlike regression analysis which compares each agency to an average agency, DEA compares each agency to best-practice agency. In the former case, comparing agencies to an average agency may produce average performance. In the latter case, agencies may have further of an encouragement to attempt to the production level of their optimal or best-practice agency. "In parametric analysis, the only optimized regression

equation is assumed to apply to each DMU. DEA, optimizes the performance measure of each DMU", providing an extra in-depth understanding about each and every individual agency.

- *Time-Series Analysis is Possible:* A technique that combines time periods into the analysis make it possible to compare an agency's performance in the year *x* against that agency's performance in any year. (*x* is a variable that represents any year).

**Limitations of DEA**

Following are some of the limitations of DEA.

- Application of DEA needs a discrete linear program for the solution of every DMU in the data set. When there are many DMUs, this calculation can be difficult. However, there are some software's that only solve DEA problems.
- Since DEA is a nonparametric technique, numerical theory checks are difficult to process to measure the reliability of results.
- Since it is an extreme point technique, if there are some errors in measurement of data for input & output variables may result in significant problems
- As efficiency scores in DEA are establish by a series of linear programming formulations, it becomes very tedious to describe the process of DEA to the non-technical background people.

**Working Concept of DEA**

A DEA model can be evaluated in two ways, input and output orientation. That is, the DEA model may center on either input reduction/ output expansion to accomplish efficiency. They are output orientation analysis that provides material on how much increase to the levels of outputs of an inefficient DMU is necessary while retaining current input levels for it to become DEA efficient, whether an input/ output orientation is used, a DEA efficient DMU will always have 100 % efficiency.

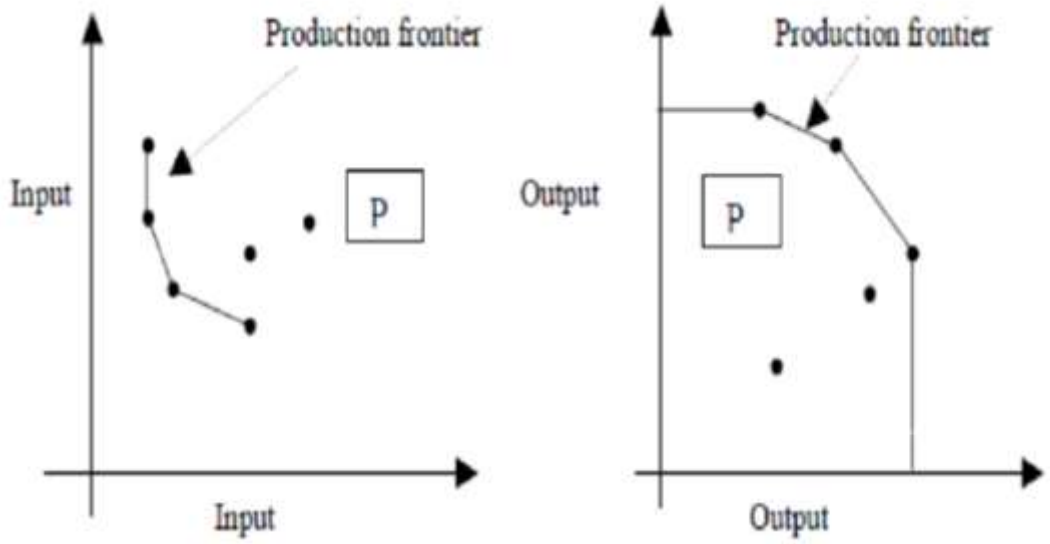



**Fig: 5.5 Input & Output Orientation**

Figure 5.5, shows the difference between input orientation & output orientation. Left figure is input orientation & right side is output orientation. Here "P "denotes the Production Possibility Set. The set of all the possible input/output combinations i.e. the efficient ones on the frontier as well as the inefficient ones, form the area that shows possibility of production and is called 'Production Possibility Set (P)'.

## 5.4 DEA SOFTWARE

The software used for the analysis is DEAP version 2.1. There are several other softwares also available for the analysis amongst which some are Microsoft Excel based interfaces. We have used the Multi stage DEA model which is capable of handling a multitude of inputs as well as outputs. In our analysis, however, we have only kept multiple inputs. Our output in each of the 3 objective sets is a single output. The number of inputs varies for each set of objectives. Also, we have done the multi stage DEA analysis in the output oriented mode. The output oriented model focuses on the expansion of the output to achieve the scores. Constant rate to scale (CRS) has been used in this study.

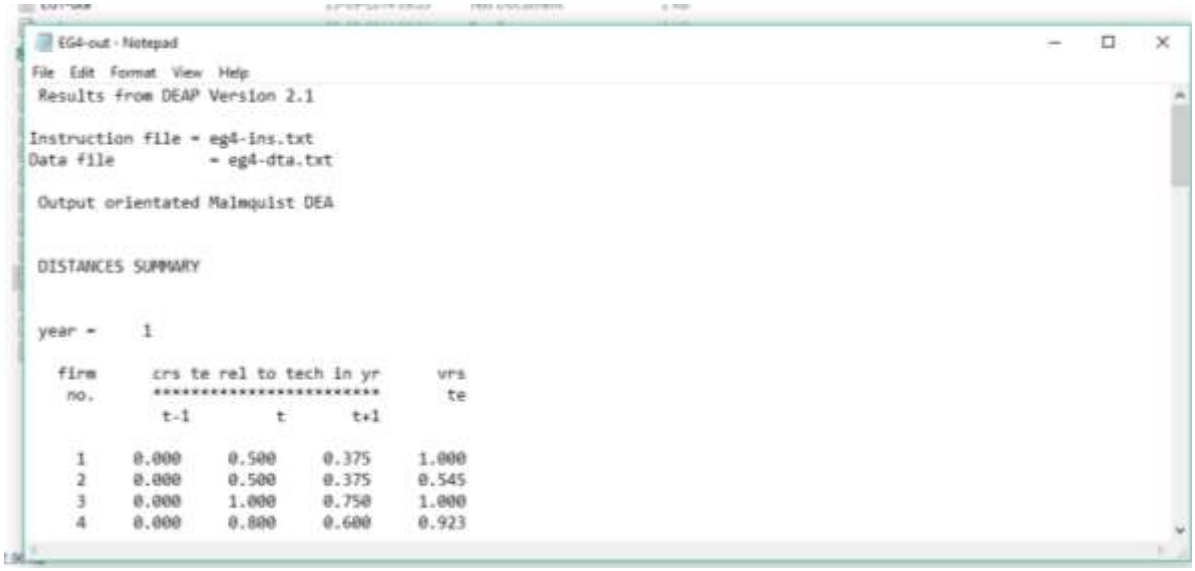



**Fig: 5.6 Illustration of the .out file in the DEAP software.**

The DEAP software allows us to create an output and input listing in the notepad and we can feed the model requirements separately in an instruction file format known as .ins file. Figure 5.6. Shows the output file. Also, we can obtain the result in a notepad file which can be conveniently converted to the Microsoft Excel format. Figure 5.7. Shows the typical execution interface of the DEAP software.

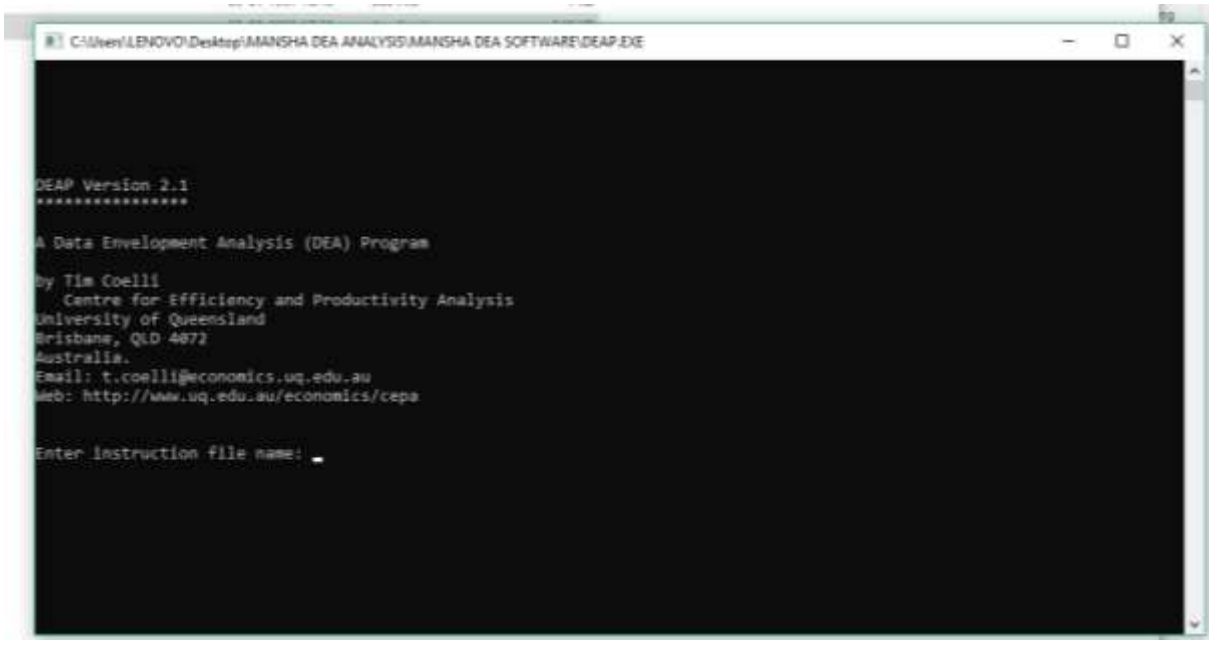



**Fig: 5.7 Snapshot of the DEAP Software Execution Interface.**

**DEA Inputs and Outputs**

A study done by (Cascajo, R. et al. 2014) reveals the performance indicators for the bus transit in European systems which were system productivity, cleanliness, information availability, comfort perception, quality of service, commercial speed, punctuality, frequency and service efficiency amongst others. This strengthened the various inputs considered for the appraisal done.

Before discussing the inputs and outputs used in the study, the definitions of the parameters used in the framing of these inputs and their respective outputs are important. The parameters tabulated in the Table 5.1. are used in the analysis. Parameters Interconnectivity convenience (**$I_C$**) and Service Time Ratio (**STR**) have been considered specifically for this analysis.

**Table: 5.1 Definitionslof the Parameterslused in the DEA.**

| | | |
|---|---|---|
| **Travel Time Ratio (TTR)** | Between a particular origin and destination TTR shall be the ratio of the travel time by public transport to the travel time by personal mode such as cars. | Ratio range 1-5 (for most trips). |
| **IVTT** | In vehicle Travel Time - Time spent in the main public transport mode in the line-haul stage. | - |
| **$I_C$** | Interconnectivity Convenience is the percentage of IVTT that is spent in the Access and Egress together. It is expressed in %. | $Ic = \frac{(ACCESS+EGRESS)}{IVTT} * 100$ |

The parameters discussed in Table 5.1, are assimilated in interrelated groups to form the sets multiple inputs and outputs. These sets are then analyzed using DEAP software in order to determine the relative efficiencies of the decision-making units (DMU's) Table 5.2. Discusses these inputs and outputs in their respective sets.

| Table: 5.2 Input and Output Sets used in DEA. | | | | |
|---|---|---|---|---|
| | **SET NAME** | **INPUTS** | **Units** | **OUTPUT** |
| 1 | **Temporal Comparison of Last Mile Connectivity** | Access Travel Time | **mins** | **Interconnectivity Convenience** |
| | | Line-Haul Travel Time | **mins** | |
| | | Egress Travel Time | **mins** | |
| 2 | **Distance Based LMC Comparison** | Access Distance | **KM** | **Travel Time Ratio** |
| | | Line-Haul Distance | **KM** | |
| | | Egress Distance | **KM** | |
| 3 | **Passenger Perception Based LMC Comparison** | Shared Auto Availability | **N.A.** | **Travel Cost** |
| | | Feeder Bus | **N.A.** | |
| | | Cycle Availability | **N.A.** | |

**DEA Results and Interpretations**

Once the efficiency analysis has been carried out, the results of each particular set of comparison amongst stations, lines or corridors are interpreted in this section.

**1. Temporal Comparison of Last Mile Connectivity**

In this set we have attempted to evaluate efficiency of the rapid rail corridor in the temporal aspect of efficiency. The DEA analysis uses input variables in terms of time taken in the first mile, line-haul and the last mile legs of the journey. The output here is taken as the interconnectivity convenience which compares the access and egress times to the total trip time. The Average Access time over the corridor was 14.32 minutes while the average egress time was 12.37 minutes across the corridor. The average time taken within the line haul mode is 27.16 minutes. Now if all these parameters are considered separately for each station then the proximal friendliness of that particular station in terms of time spent on first and last legs of transport can be seen. Further, the efficiency scores shall indicate the comparative levels of connectivity each of these stations provide in their respective catchment areas.

**Table:5.3 DEA Output Result for Temporal Comparison**

| Name of Station | RANK | EFFICIENCY | SLACK IN INPUT 1 | SLACK IN INPUT 2 | SLACK IN INPUT 3 |
|---|---|---|---|---|---|
| DLF Phase-3 | 1 | 1 | 0.00 | 0.00 | 0.01 |
| Molsarai Avenue | 7 | 0.40 | -0.56 | 0.03 | -0.67 |
| Indusland Cyber City | 4 | 0.66 | -0.40 | -0.09 | -0.44 |
| Vodafone Belvedere Tower | 2 | 0.86 | -0.07 | -0.02 | -0.34 |
| DLF Phase-2 | 4 | 0.66 | -0.34 | -0.04 | -0.43 |
| Sikanderpur | 3 | 0.71 | -0.39 | -0.11 | -0.41 |
| DLF Phase-1 | 7 | 0.40 | -0.58 | -0.03 | -0.69 |
| Sector 42-43 | 2 | 0.86 | -0.32 | -0.01 | -0.09 |
| Vivo Sector 53-54 | 5 | 0.53 | -0.39 | -0.07 | -0.48 |
| Sector 54 Chowk | 6 | 0.43 | -0.43 | -0.05 | -0.52 |
| Sector 55-56 | 8 | 0.21 | -0.41 | -0.03 | -0.61 |

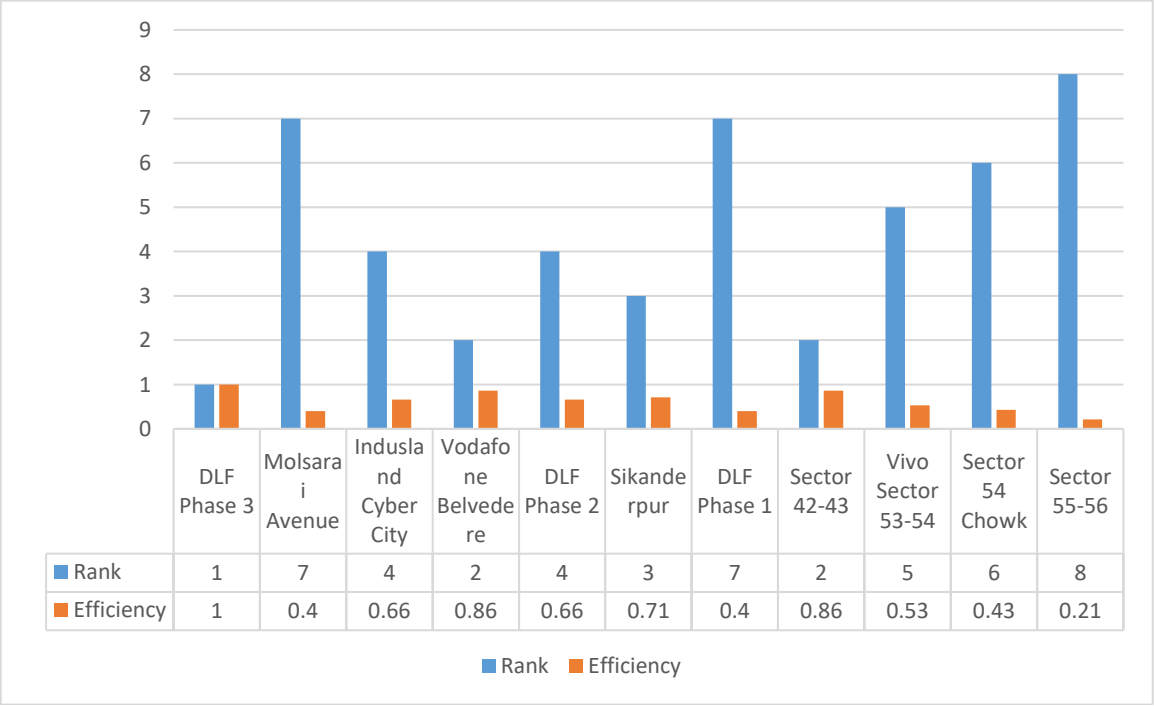



**Fig: 5.8 Rank & efficiency of respective station.**

## 2. Distance Based LMC Comparison

In this set the distance-based comparison is taken into consideration with respect to the last mile connectivity. The total distance covered for each leg respectively has been considered for the inputs separately. Further, The travel time ratio which is the time taken over a particular distance from public transport compared to the private transport is taken as the output indicator.

**Table:5.4 DEA Output Result for Distance Based Comparison**

| Name of Station | RANK | EFFICIENCY | SLACK IN INPUT 1 | SLACK IN INPUT 2 | SLACK IN INPUT 3 |
|---|---|---|---|---|---|
| DLF Phase-3 | 1 | 1 | -0.21 | -0.01 | -0.29 |
| Molsarai Avenue | 8 | 0.14 | -0.32 | -0.12 | -1.71 |
| Indusland Cyber City | 4 | 0.44 | -0.27 | 0.00 | -1.42 |
| Vodafone Belvedere Tower | 2 | 0.57 | -0.22 | -0.02 | -0.31 |
| DLF Phase-2 | 3 | 0.47 | -0.21 | -0.01 | -0.38 |
| Sikanderpur | 5 | 0.35 | -0.33 | 0.00 | -0.46 |
| DLF Phase-1 | 6 | 0.29 | -0.28 | 0.00 | -0.56 |
| Sector 42-43 | 5 | 0.35 | -0.29 | -0.02 | -0.51 |
| Vivo Sector 53-54 | 5 | 0.35 | -0.31 | -0.10 | -0.49 |
| Sector 54 Chowk | 4 | 0.44 | -0.25 | -0.02 | -0.40 |
| Sector 55-56 | 7 | 0.27 | -0.31 | -0.05 | -1.11 |

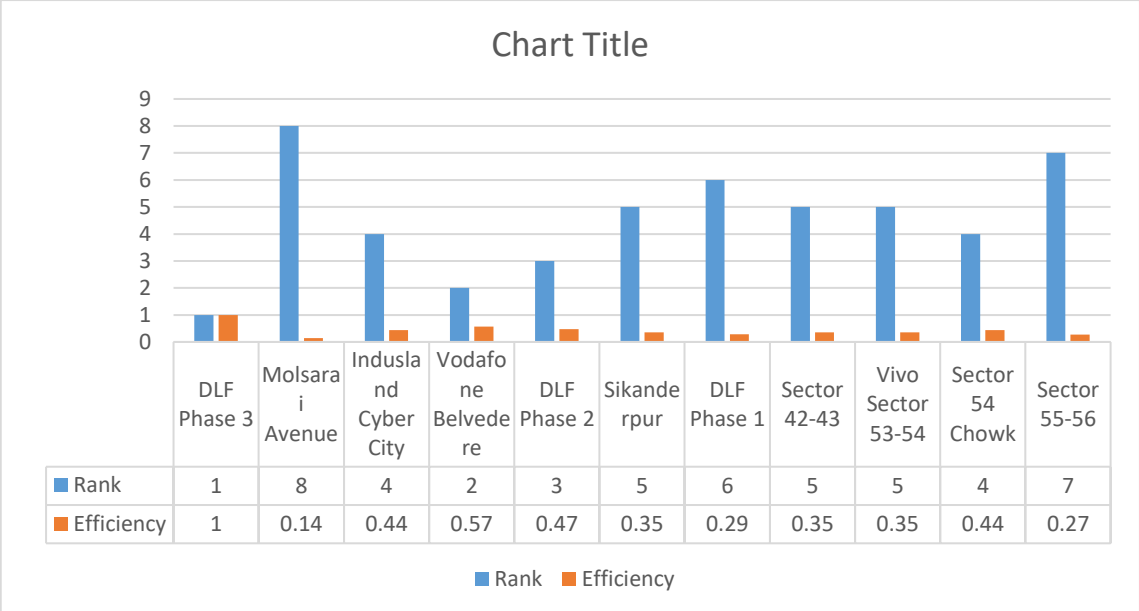



**Fig: 5.9 Rank & efficiency of respective station.**

### 3. Passenger Perception Based LMC Comparison

In this set, the passenger perception about the various possible modes of the last mile are taken into consideration. The modes considered here are shared auto, cycle and feeder bus. Walking as a mode was not taken here because it was and individual's efficiency related matter and the stakeholders cannot do much about dissuading to use the mode or not. However, availability of the above mentioned three modes was very much found to be in the unorganized sector of public transportation in the Gurugram area. Further, the output was taken as the travel cost as this was one of the direct indicators as to which particular mode was supposed to be taken up by the passenger.

**Table:5.5 DEA Output Result for Passenger Perception**

| Name of Station | RANK | EFFICIENCY | SLACK IN INPUT 1 | SLACK IN INPUT 2 | SLACK IN INPUT 3 |
|---|---|---|---|---|---|
| DLF Phase-3 | 8 | 0.14 | -0.39 | -0.65 | -1.31 |
| Molsarai Avenue | 3 | 0.47 | -0.32 | -0.43 | -0.24 |
| Indusland Cyber City | 2 | 0.57 | -0.16 | -0.23 | -0.32 |
| Vodafone Belvedere Tower | 7 | 0.27 | -0.32 | -1.21 | -0.61 |
| DLF Phase-2 | 6 | 0.29 | -0.31 | -0.51 | -0.63 |
| Sikanderpur | 1 | 1 | -0.10 | -0.16 | -0.23 |
| DLF Phase-1 | 5 | 0.35 | -0.22 | -0.64 | -0.43 |
| Sector 42-43 | 4 | 0.44 | -0.12 | -0.54 | -0.31 |
| Vivo Sector 53-54 | 4 | 0.44 | -0.17 | -0.51 | -0.39 |
| Sector 54 Chowk | 1 | 1 | -0.17 | -0.15 | -0.27 |
| Sector 55-56 | 5 | 0.35 | -0.27 | -0.58 | -0.58 |

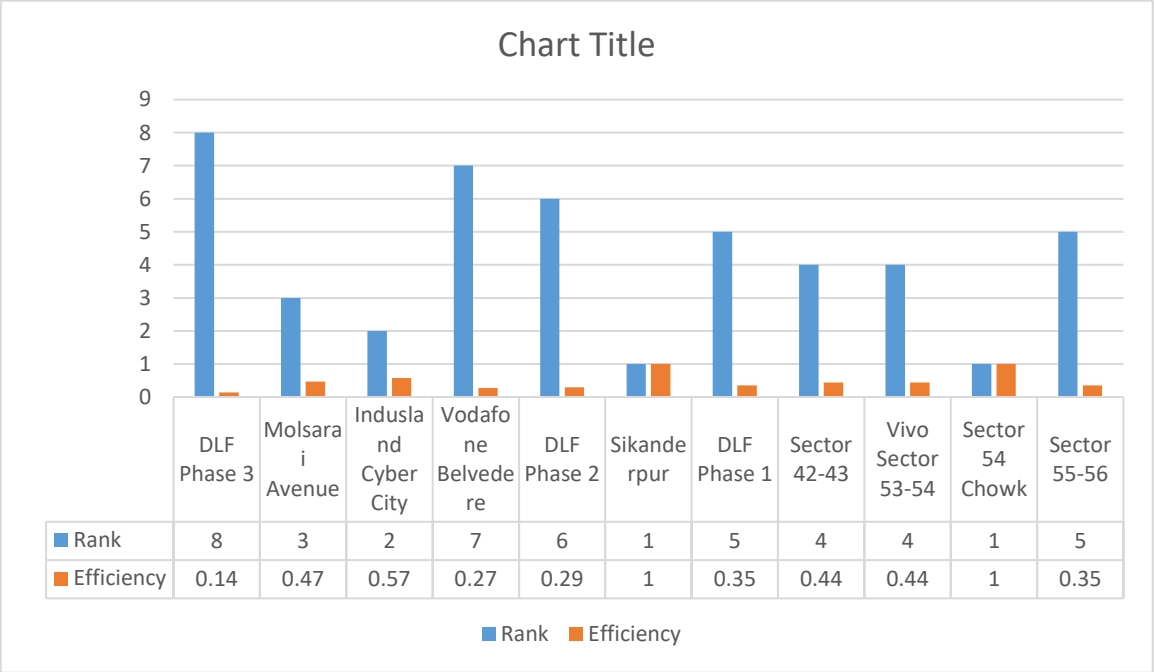



**Fig: 5.10 Rank & efficiency of respective station.**

# CHAPTER-6

# POLICY AND RECOMMENDATION

Transport Policies in the past were almost silent on the importance of last mile connectivity for transit system. While transport policies to talk about promoting public transport, multi modal integration and non-motorized transport, but the policy in respect to last mile connectivity should also be made.

There are Several key infrastructural facilities which can help to improve the last mile experience which should be incorporated in urban transport system.

**1. Interchange facilities with different modes**

The most critical requirement is the creation of multimodal interchange facilities should be provided, where the commuters can change modes or routes without much time penalty and in safely without conflicting with our transport modes, moreover at all interchange points should be able to cater to interchange with personal modes (such as car, bike, cycle) and as well as with public modes (such as taxi, auto, rickshaw).

**2. Parking Facilities**

Due to high vehicle ownership and limitation of providing public last mile modes to all locations, commuters should be provided with a parking facility at the station so that park and ride could be done, parking at the station increases the comfort to passengers.

**3. Self-driven battery-operated cycle facilities**

A self-driven battery cycle facility should be provided at the station where the one could charge and park and ride, this will also help in increasing the share of nonpolluting vehicle environment, cycle lanes for safe commuting will also enhance the safety of commuters.

**4. Integration of various modes plying on the same route of transit services**

A modal integration with different modes should be made such that instead of providing services parallel to the transit system they should provide services perpendicular to the

transit station (which will automatically act as a feeder system) such that commuter can change the mode at the transit station.

**5. Unified fare structure**

Due to the availability of cheaper mode option on the same route of transit system the ridership gets affected due to multiple reasons but dominated due to the cheaper option regardless to the level of comfort, hence the fare should be as minimum as possible such that it could attract all potential commuters.

**6. Free feeder Bus service facilities**

Free feeder bus service should be provided to the metro stations as observed from commuter perception survey for both User & Non User survey that feeder bus service should be provided for Indusland cyber city and Molsarai Avenue.

# CHAPTER-7

# CONCLUSION

- The basic aim of the current research is to evaluate the Last Mile connectivity for Gurugram Rapid Metro. Various Survey Methods like Inventory Survey, Metro user commuter and Non-Metro user questionnaire survey were carried out in order to evaluate the last mile connectivity and know the commuter's perception with the connectivity to get the access and egress from rapid metro station.
- Metro user survey results show that approximately equal number of males and females use the rapid metro and maximum user of the age group were from 20 to 29 years and 30 to 39 years, which directly proves Gurugram rapid metro is surrounded young generation working class which has many multinational companies in its vicinity
- Mostly metro was used for office or work purpose and the maximum commuter were using walk as an access and egress mode as all the work place were near to it while commuters whose destination was within the distance of 0.5 KM to 2 KM used Shared auto for the commuting purpose.
- After a deep study in Metro user survey, commuter who's destination lies within the 1 km radius were very much satisfied with metro services but the modes to access them is very problematic and it leads to overall depletion of metro evaluation score as reported DEA software.
- Non-Metro user survey also presents that commuter who are taking other modes other than rapid metro in the same location, provides information that due to non-conformity of some of the issue like fare structure, easy and comfortable alternative etc. leads to lacking in ridership
- Fare collection integration with DMRC helps rapid metro to get more and more passenger survey results reveals that more than 50% of the Delhi metro user were interchanging at Sikanderpur station which proves to be a very good ridership with DMRC.
- Non-Metro user who were traveling with their personal modes (Car or bike), were very much comfortable with their own mode and people who wanted to travel with rapid metro had a issue of lack of parking space on metro station, as Gurugram have high Pvt. Vehicle ownership so commuter prefer to take his personal vehicle to metro station and park vehicle and continue his journey further with rapid metro.

- Many cheaper alternative modes are also available on the metro corridor which is also demotivating the ridership as the road infrastructure on the metro corridor is 16 lane high speed corridor
- The DEA analysis shows that egress part is making the entire network less efficient
- As per DEA analysis it is also seen that non availability options are hampering the efficiency of rapid metro corridor

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# ANNEXURE-1

**THAPAR INSTITUTE OF ENGINEERING TECHNOLOGY PATIALA**

M. TECH THESIS-: EVALUATION OF LAST MILE CONNECTIVITY FOR RAPID METRO GURUGRAM

This study is taken up to evaluate the Last Mile connectivity for Rapid Metro Gurugram in the State of HARYANA.

*Note: It is hereby assumed that the data collected would be utilized for academic purpose only.*

## INVENTORY SURVEY

**Station Name: _____ Date: _____**

| | |
|---|---|
| **PEDESTRIAN ACCESS FACILITIES FACILITITES** | Are there any sidewalks present in the area? Yes No<br>If yes, what is the width of the sidewalk? _____<br>How many people travel use the sidewalk in a 5 min interval?<br>0–10 10–30 30–50 >50<br>Does it happen that people abandon the sidewalk and walk on roads? Yes No<br>Is the sidewalk clean? Yes No<br>Is the sidewalk mounted with guard rails? Yes No<br>Is the sidewalk mounted with unnecessary obstructions? Yes no (if yes, what obstruction) _____<br>What is the height of the sidewalk? _____<br>Are special provisions made for handicapped pedestrians? (if yes what provision) Yes No<br>Are the pedestrian paths broken? Yes No |
| **ACCESS FACILITIES** | Are proper lightening facilities available on pedestrian sidewalks? Yes No<br>Are there skywalks on the station? Yes No<br>Is there pedestrian foot over bridges (F.O.B) present in the station premises? Yes No<br>Are ramps/escalators/elevators provided? Which ones? Yes No<br>Are there security arrangements in the station area? Yes No<br>Are there how many hoardings/advertisement boards? Yes No<br>0–1 1–5 5–10 >10<br>Are ramps/escalators/elevators provided on subways? Yes No<br>Are there proper drainage facilities in subways given? Yes No<br>Is proper signage provided? Yes No<br>Are there security arrangements? Yes No<br>Is there any provision for the luggage trolley? Yes No<br>What type of facilities are in use for announcing travel times/arrivals/departures?<br>Manual announcement Recorded announcement VMS Board Scrolling Marquee<br>Are there doorways to the access areas for disables users? Yes No<br>Is there a information/query window at the station? Yes No<br>Is the flooring proper to walk upon? Yes No<br>Concrete anti-skid tiles Granite/Stone Block pavement<br>Can elderly easily move around in the station premises? Yes No<br>Is there adequate floor pattern or braille signage for blind people? Yes No |

| | | |
|---|---|---|
| **FACILITIES FOR CYCLISTS** | Are there cycle tracks provided? Yes No<br>If yes what is the width of the cycle track? _____<br>Are any signage provided for bicycle users? Yes No<br>How many people use bicycles for an interval of 5 minutes?<br>0─10 10─30 30─50 >50<br>Do the advertisement boards cause any threat to the bicycle users? Yes No<br>Is there any bicycle parking facility available? Yes No<br>If a separate cycle track is present, how many lanes it has? Yes No<br>1 2 > 2<br>Are cycle tracks present on both sides of the station for access and egress? Yes No<br>What is the width of one lane? _____<br>Are clear road markings present for cycle tracks on the carriageway of intersections? Yes No | |
| **PARKING FACILITIES** | The parking facility type provided? Yes No<br>Underground on street above ground At-Grade<br>Approximate number of parking 2W _____ 4W_____ Both _____<br>Approximate surface area parking space _____<br>Total number of bays occupied<br>Is kerb parking observed? Yes No<br>Is there any multi storeyed parking garage? (if yes how many storeyed?) Yes No<br>Are there any security arrangements in the parking lot? Yes No<br>Are there proper lightening amenities in the parking lot? Yes No<br>Is there any litter or garbage in the parking lot? Yes No<br>Is it a pay parking? Yes No<br>Is the parking managed by a community or by station? _____<br>Is there any reserved parking for disabled people? Yes No<br>Are there CCTV's installed in the parking lot? Yes No<br>If pay parking, how much is the fare? 2W_____ 4W _____<br>Is the parking time limited? (how much time) Yes No<br>Is there a monthly pass system for parking? Yes No<br>Is there adequate signage available for parking or no parking zones? Yes No<br>How much time is spent in fare collection? _____ | |
| **POSSIBLE CONNECTIVITY TO THE STATION** | Modes | Remarks |
| | Bus<br>Feeder bus<br>Taxi/Auto<br>Share Auto<br>Battery Rickshaw<br>Cycle Rickshaw<br>Personal Mode<br>Walk | |
| | Any Remarks or observation for the station and its location | |

# ANNEXURE-2

## THAPAR INSTITUTE OF ENGINEERING TECHNOLOGY PATIALA

M. TECH THESIS-: EVALUATION OF LAST MILE CONNECTIVITY FOR RAPID METRO GURUGRAM

This study is taken up to evaluate the Last Mile connectivity for Rapid Metro Gurugram in the State of HARYANA.

*Note: It is hereby assumed that the data collected would be utilized for academic purpose only.*

## METRO USER SURVEY

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Commuter Demographics Characteristics** | | | | | | | |
| 1 | Age Group | 0-9 ◯ | 10-19 ◯ | 20-29 ◯ | 30-39 ◯ | 40-49 ◯ | 50-59 ◯ |
| 2 | Gender | Male ◯ | Female ◯ | | | | |
| 3 | Monthly Income (₹) | Less than ◯ ₹5000 | ₹5,000 to ◯ ₹15,000 | ₹15,001 to ◯ ₹35,000 | ₹35,001 to ◯ ₹50000 | ₹50,001 to ◯ ₹75,000 | More than ◯ ₹75,000 |
| 4 | Employment Status | Govt. Job ◯ | Pvt. Job ◯ | Self Employed ◯ | Student ◯ | Other ◯ | |
| 5 | Vehicle Ownership | 4-Wheeler ◯ | 2-Wheeler ◯ | Bicycle ◯ | None ◯ | | |
| 6 | House Hold Size | 1 ◯ | 2 ◯ | 3 ◯ | 4 ◯ | 5 ◯ | More than 5 ◯ |
| 7 | Frequency of trips | Once ◯ | Twice ◯ | Thrice ◯ | Quad ◯ | | |
| 8 | Number of Co Passenger | 1 ◯ | 2 ◯ | 3 ◯ | More than 3 ◯ | | |
| 9 | Expenditure on daily Travel (₹) | O to 20 ◯ | 20 to 50 ◯ | 50 to 80 ◯ | 80 to 120 ◯ | More than 120 ◯ | |
| 10 | Trip Purpose | Education ◯ | Office ◯ | Work ◯ | Shopping ◯ | Others ◯ | |

| **Trip Information (Metro User)** | | | |
|---|---|---|---|
| **Origin** | | **Destination** | |
| Access Distance Travelled | | Egress Distance Travelled | |
| Time taken | | Time taken | |
| **RAPID METRO Trip Distance** | | | |

**How do you commute to RAPID METRO Stations?**

Walk ◯ Cycle ◯ $2W_{(D/P)}$ ◯ $4W_{(D/P)}$ ◯ Shared Auto ◯ Taxi(Auto) ◯ BUS/Shuttle ◯

**How do you commute from RAPID METRO Station to Destination?**

Walk ◯ Cycle ◯ $2W_{(D/P)}$ ◯ $4W_{(D/P)}$ ◯ Shared Auto ◯ Taxi(Auto) ◯ BUS/Shuttle ◯

**Are you Satisfied with the Connectivity?** Yes No

**If no, Give reason** _____

**How do you find Metro Service?** Very Poor ◯ Poor ◯ Satisfactory ◯ Good ◯ Very good ◯

**Is Metro Cheap or Costly?** Very Cheap ◯ Cheap ◯ Reasonable ◯ Costly ◯ Very costly ◯

**How fast do you find Metro?** Very slow ◯ Slow ◯ Reasonable ◯ Fast ◯ Very fast ◯

**Do you get seating in Metro?** Always ◯ Sometimes ◯ Very few times ◯ Never ◯

**Commuter Satisfaction Survey**

| Condition | Yes | No | Remarks |
|---|---|---|---|
| **It's easy to find routes and travel** | | | |
| **Is it convenient and comfortable way to travel** | | | |
| **Do you feel safe in the day ?** | | | |
| **Do you feel safe in the night ?** | | | |
| **This station/stop area is clean ?** | | | |
| **There are enough places to sit?** | | | |
| **There are places to buy food and beverage nearby** | | | |
| **There is enough shelter from sun and rain** | | | |
| **The information signs here are helpful** | | | |
| **Do you know where to contact in case of an emergency?** | | | |
| **Is the station lighting adequate?** | | | |
| **Is this an easy place to transfer for bus or another mode of transport** | Somewhat | Easy Not easy at all | Easy Not easy at all |
| **What suggestion would you like to give to develop this station into a better multimodal hub to ease the travel for passengers** | | | |
| **Do u find that your time is wasted in transfers and waiting ? If yes how much time?** | | | |
| **Do you prefer to travel with this system?** | Yes | Not at all | Only if no which alternative _____ |
| **The system is better than road travel** | | | Only in rush hours I travel from Public transit to avoid traffic |
| **How good is the Access and Egress facilities at the station** | Very Poor ○ | Satisfactory ○ | Good Very good ○ |
| **Are there good restrooms in the station Premises** | Very Poor ○ | Satisfactory ○ | Good ○ Very good ○ |

| **If option of these services is given which you will adopt** | | | | |
|---|---|---|---|---|
| **S.No.** | **Last Mile Options** | **YES** | **NO** | **Reason for rejection** |
| 1 | Paddled Cycle | | | |
| 2 | Battery operated Cycle | | | |
| 3 | Battery Operated Cycle rickshaw | | | |
| 4 | Feeder Bus | | | |
| 5 | City Bus | | | |
| 6 | Shared Auto | | | |
| 7 | Taxi/Cab/OLA/UBER/OTHERS | | | |
| 8 | Air-conditioned pod taxi | | | |

# ANNEXURE-3

## THAPAR INSTITUTE OF ENGINEERING TECHNOLOGY PATIALA

M. TECH THESIS-: EVALUATION OF LAST MILE CONNECTIVITY FOR RAPID METRO GURUGRAM

This study is taken up to evaluate the Last Mile connectivity for Rapid Metro Gurugram in the State of HARYANA.

*Note: It is hereby assumed that the data collected would be utilized for academic purpose only.*

## NON-METRO USER SURVEY

**Commuter Demographics Characteristics**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | Age Group | 0-9 ⬭ | 10-19 ⬭ | 20-29 ⬭ | 30-39 ⬭ | 40-49 ⬭ | 50-59 ⬭ |
| 2 | Gender | Male ⬭ | Female ⬭ | | | | |
| 3 | Monthly Income (₹) | Less than ₹5000 ⬭ | ₹5,000 to ₹15,000 ⬭ | ₹15,001 to ₹35,000 ⬭ | ₹35,001 to ₹50000 ⬭ | ₹50,001 to ₹75,000 ⬭ | More than ₹75,000 ⬭ |
| 4 | Employment Status | Govt. Job ⬭ | Pvt. Job ⬭ | Self Employed ⬭ | Student ⬭ | Other ⬭ | |
| 5 | Expenditure on daily Travel (₹) | O to 20 ⬭ | 20 to 50 ⬭ | 50 to 80 ⬭ | 80 to 120 ⬭ | More than 120 ⬭ | |

**Trip Information (Non-Metro User)**

**Origin : _____** **Destination : _____** **Trip Distance : _____**

Mode Adopted (2W, 4W, Auto, Rickshaw, Bus, Taxi, Misc.) Walk ⬭ Cycle ⬭ $2W_{(D/P)}$ ⬭ $4W_{(D/P)}$ ⬭ Shared Auto ⬭ Taxi ⬭ City Bus/Shuttle ⬭

**Access Distance Travelled to first mode: _____** **Time taken: _____**

Change of Mode adopted from 1st mode to 2nd Mode Walk ⬭ Cycle ⬭ $2W_{(D/P)}$ ⬭ $4W_{(D/P)}$ ⬭ Shared Auto ⬭ Taxi ⬭ City Bus/Shuttle ⬭ **Transfer Location _____**

**Are you Satisfied with the Connectivity?** Yes ⬭ No ⬭

If Yes, Give reason _____

**Have you ever traveled in rapid metro?** Yes ⬭ No ⬭

**Why don't you adopt Rapid Metro for the means of your travel?**

Expensive ⬭ Time-Consuming ⬭ Poor Service ⬭ Less Comfortable ⬭

Less Connectivity to Station ⬭ Long Ques at security ⬭ Unsafe ⬭

Avoid Multiple Mode as it doesn't connect to egress location ⬭

**If option of these services is given which you will adopt to use Rapid Metro as a option**

Paddled Cycle ⬭ Battery operated Cycle ⬭ Battery Rickshaw ⬭ Feeder Bus ⬭

City Bus ⬭ Shared Auto ⬭ Taxi/Auto/OLA/UBER/OTHERS ⬭ Air-conditioned pod taxi ⬭

Last Mile Connectivity

ORIGINALITY REPORT

| 14% | 7% | 5% | 9% |
|---|---|---|---|
| SIMILARITY INDEX | INTERNET SOURCES | PUBLICATIONS | STUDENT PAPERS |

PRIMARY SOURCES

| | | |
|---|---|---|
| 1 | Submitted to Thapar University, Patiala<br>Student Paper | 4% |
| 2 | Alshalalfah, B. W., and A. S. Shalaby. "Case Study: Relationship of Walk Access Distance to Transit with Service, Travel, and Personal Characteristics", Journal of Urban Planning and Development, 2007.<br>Publication | <1% |
| 3 | www.worldtransitresearch.info<br>Internet Source | <1% |
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| 7 | www.transed2012.in<br>Internet Source | <1% |
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| | networks", Transportation Research Part A: Policy and Practice, 2012<br>Publication | |
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