Enhancing Last Mile Connectivity in Bengaluru Metro - A Case Study

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Abstract - Bengaluru is one of the fastest growing cities in India and expanding vastly in all directions.As a result of larger floating population with increasing existing population of the city, there has been increase in vehicular population adding to extreme congestion and air pollution on the city roads.The mass rapid transit system (MRTS) was encouraged, so that commuters could start using public transport more and more, instead of using private vehicles. It is necessary to understand the actual origin of traffic , for that purpose Origin and destination studies are carried out by interview techique and related data are collected. Last mile defines the difficulty in getting for the people from a transportation hub, to their final destination.In this study, the problems associated with last mile connectivity of Bengaluru's Mass Rapid Transit System named as "Namma metro" is evaluated using survey123 Arc GIS app. This paper presents and analyzes the results from a case study in which new mobility enterprises are piloted as last-mile solutions at a metro station in Bengaluru. Commuter preference to mass transit system (MTS) has increased since its launch but the traffic congestion has not at all reduced significantly. Inspite of increase in commuter population in metro and hence the fuel consumption. Metro has emerged as safe mode of transport, but still commuters continue with unsafe modes of transport due to limited connectivity of the metro rail. The outermost destination covered by BMTC services and feeder facility has to be improve by providing more number to last mile destination for the different sectors.

Index Terms— Origin And Destination Study , Commuters Interview Techique, Last-Mile Connectivity, Traffic Congestion, Mass Rapid Transit System (MRTS), Survey123 Arc GIS software

1 INTRODUCTION

THE transportation system play vital role in a part of any country as it contributes to the social and economic development. Transportation built closely with well oraganized movement and development of humans throughout history of world. Transportation played a part of industrial, economic, social and cultural development of all region in every commodity produced which includes agricultural to industries at various stage of production to distribution. The transportation system includes planning, design, developing, maintainance and improvement.

The increasing vehicular traffic on the urban road in network demand effective measure of the traffic control on roads – networks,mixed traffic creates the congestion, traffic jam in road networks. The land use feature and transportation system is inter-dependent as it contribute one another other in improvement and expanding the transportation network. If system is efficient, safe and economical, the development of the city improves in better accessibility. Mass rapid transit system projects like metro rails are expected to improve traffic and road safety conditions (reduced vehicular traffic, traffic congestion, road accidents etc.) and environmental conditions (air and noise pollution) in urban areas

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Therefore, the present study was conceived to assess the overall potential and efficiency of the metro rail in terms of easing the traffic scenario in Bengaluru city through commuter perception. The use of metro services by public is known to decongest urban traffic. Public can use metro services when the outermost destinations are directly accessible to metro stations. Issues with connectivity from home or destinations to access metro can lead to choice of modal shift. In this regard, last mile connectivity study is undertaken to evaluate the last mile problems. Last mile connectivity defined as movement of public also goods from a transportation area to their a final destination such as home or workplace. This is usually used in telecommunications, chain management and transportation planning describing transportation efficiency.When users have difficulty getting from their starting location to a final transportation network, the scenario is alternatively known as the problem in first mile. Vice versa Last mile problem refers to difficulty getting conveyance from transportation network to the users destination. This problem can be evaluated using Last mile Connectivity analysis using geospatial techniques using Arc GIS . This study is taken up to evaluate the Last mile connectivity of Bengaluru's Mass Rapid Transit System named as "Namma metro". The study encompasses various aspects of Last mile connectivity such as metro station wise connected Last mile destinations, number of buses operating in the metro station nearest bus stops which can access metro services, the density of buses in different stretches of the transport route noted.

1.1 Study Objective

- The objective of present research is to Determine catchment of a metro station by Commuter OD survey and land use around metro station
- Identify areas underserved by public transport or IPT within the catchment of a metro station by Available PT and IPT and Frequency of PT and the routes (from BMTC) and Areas served by IPT's (By interviewing IPT drivers)
- Identifying the shortcomings in physical infrastructure within the catchment area that does not support last mile commute (PT, shared mobility, walking) by Condition of the roads for last mile connectivity and LOS,Condition of footpaths for pedestrian movement
- Critiquing adequacy of existing services (availability, frequency, cost) by Commuter's survey for sufficiency of service available preference of mode (what and why)
- Ascertain if last mile connectivity modes are available within 150m of a metro station by Reconnaissance survey 150m around the metro stations

1.2 Study Area and Need Of Study

The study area selected was the North –South corridor of the metro rail, also known as Green line which stretches across 24.2 km from yellachenahalli in the south and terminates at Nagasandra. It consists of 24 stations. In that, based on ridership parameter Jayanagara metro station is selected with the latitude and longitude.The Latitude: 12°59'27" N and Longitude: 77°39'09" E on the green line corridor.

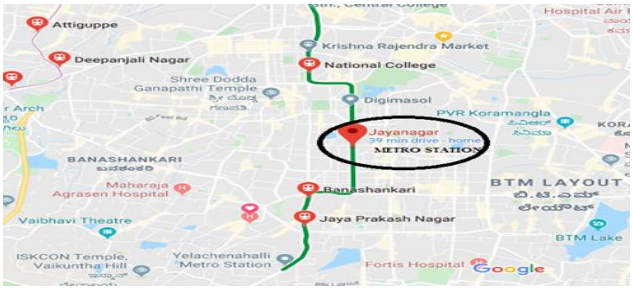

Figure 1. Schematic map of Bengaluru Metro jayanagar station (source google map)

With increasing traffic congestion coupled with unprecedented growth of private vehicles, road accidents and issues of road safety and increasing air pollution, the urban planners and policy makers consider metro rail project as inevitable for efficient transport system in urban environment. In this context, the focus of the present study was to assess the overall performance of the Metro Rail in terms of its impact on easing the traffic congestion, reduction in vehicular count, accessibility options and its influence on commuters. Also improving the public transport system and feeder service near by last mile connectivity This findings can be useful for improving ongoing metro rail services in the study area and other metropolitan cities.

1.3 Profile of Bengaluru Metro

The Bengaluru Metro project, popularly known as "Namma Metro", was being implemented by the Bengaluru Metro Rail Corporation Limited (BMRCL) - a joint venture of the Government of India and the Government of Karnataka. The Bengaluru Metro project was undertaken in 2007. The East-West corridor is 18.1 km long, and starts from Baiyappanahalli in the East and ends at Mysore Road terminal in the West with 17 stations.The North-South corridor is 24.2 km long, from Nagasandra in the North to yellachenahalli in the South with 24 station.

A. Growth of Motor Vehicles

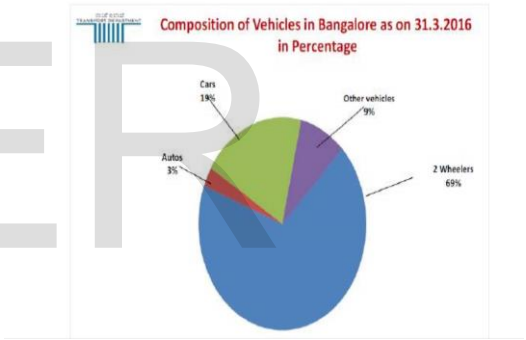

Figure 2. Annual report of 2015-16, Transport dept. GOK (source)

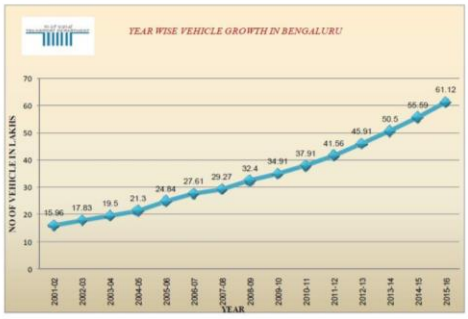

Figure 3. vehicle growth (source BMRCL)

B. Public Transport System

Buses, auto rickshaws and taxis are the various modes of transport available in the city. Bengaluru Metropolitan Transport Corporation operates the buses with a fleet size of 6,159 buses as on March 13, 2017 (BMTC 2017) City is expanding in all directions, and roads are already congested, buses alone are not capable of coping with the heavy commuter demand. Buses carry about 2.4 million passengers per day like modal share of about 45%. But bus service is not adequate and it is overcrowded and not fully reliable for commuters (CTTP, 2011) Hence, an efficient public transport system is required to ease the traffic scenario in Bengaluru

C. Issues of Urban Transport in Bengaluru

- ❖ Bengaluru city has seen exponential growth over the last 50 years
- ❖ The city's population crossed 5 million & last three decades, the vehicular population is growing at an average rate of 25% per annum.
- ❖ Resulted in traffic congestion and low vehicular speed &Various other factors
- mixed type of traffic
- no widening of the roads
- no laying of new roads to accommodate newer vehicles,
- frequent traffic jams at road intersections are some of the major issues & also increase of Air Pollution in the City

Ridership trend is Ever since the inception of the metro rail, there has been increase in ridership of passengers. Although the metro rail was operational since 2011, only parts of the EastWest corridor were functional until 2015, when the complete stretch was fully operational. As per the data obtained from BMRCL, in July 2016 the ridership was 35, 22,412 which saw a fall in September, 2016 by 3, 86,839. Later there was gradual increase in ridership of passengers from October, 2016 to June 2017. The highest recorded ridership (47, 25,648) was seen in the month June, 2017.

Figure 4. Ridership trend (source BMRCL 2017)

2 Background Literature

The literature review related to HCHE has been divided in sections. Chidambara (2012) studied in transportation, first- and last-mile connectivity refer to the end segments of a journey undertaken by public or mass transit, connecting origin and destination points to stations or stops on the transit network. An aspect that has been shown to have great potential for improving the quality and level of service of public and mass transit, the provision of economical and convenient last mile connectivity is nevertheless an area that has been greatly neglected in Indian cities. There is extensive research to suggest that lack of good connectivity between mass transit stations and the end points of commutes may dissuade commuters from using public transit and impact ridership (Cervero 1998, Cheong and Toh 2010, Givoni and Rietveld 2007).

Improving the public transport system,Delhi city (2015) The research discuss about overview of Delhi and present conditions at selected five metro stations by doing surveys regarding last mile connectivity. The important questions that the project tries to address are an assessment of comfort, time, space, cost, incurred in the LMC as a ratio of the total journey for rapid transportation system users; user preferences and alternatives available, for LMC and in the end, whether lack of efficient LMC options is a decisive element in the commuter's choice of secret modes and how it involves the overall in the efficiency of a public transit system.

Sharat Sharma(2014)Integration of a Metro Rail with Other Transit Systems -Case Study Delhi Metro Transit Systems - Case Study Delhi Metro UMI, aim to develop Integrated Transport Planning Integrated Rationalfare system Transitoriented Development Transitoriented Development Unified,Transport/LandAuthority by minimise the need to transfer but maximize the opportunity to transfer

Chaitanya Kanuria, Krithi Venkata, Sudeept Maitia, Pawan Mulukutlaa (2019) Leveraging innovation for last-mile connectivity to mass transit This paper presents and analyzes the results from a case study in which new mobility enterprises plan are piloted as last-mile connectivity solutions at metro station in Bengaluru They have a high perceived time savings among users, and it is found that there is a measurable modal shift from a personal vehicles to these solutions for bridging the last mile gapping. At the same time, the case study shows that there is need for supporting regulation of frameworks and greater multimodal integration for enabling public-private collaboration for seamless and sustainable in urban mobility.

Study on last mile connectivity with Metro Rail Stations to improve Metro Rail patronage in CMRL. LUTP Project P.K.Parthiban, K.Srinivasan To identify few of the functional Metro Stations of CMRL and verify for connectivity to nearby transportation hub, dense population areas, commercial activity centres, business complexes and find ways to improve

connectivity to Metro stations Study various parameters around station to improve last mile connectivity Means to Improve cycling and walking patronage around stations

The Ministry of Urban Development, Government of India has come up with the "National Urban Transport Policy (NUTP)" approved on 4th April 2006. A key distinction of NUTP (Ministry of Urban Development, 2006) is on the notion of addressing mobility of „people" over „vehicles". Thus, the NUTP has the primary aim to ensure easily accessible, safe, affordable, quick, comfortable, reliable and sustainable mobility for all Underlining the urgent need for sustainable urban mobility, the National Urban Transport Policy of the Government of India recommends all cities with populations of over one million inhabitants to plan for mass rapid transit systems (Ministry of Urban Development, 2014). In response, the Centre and various State governments are investing about two trillion INR (USD 31.27 billion) in building almost 900 kilometers of metro rail-based mass rapid transit systems (MRTS) across 18 cities in the country (Bhatt, 2017). At last count, about 400 kilometers of metro rail corridors are operational in ten cities, as seen. Metro rail networks in Indian cities Metro rail network Operational length (in km) Delhi Metro 217.90 Bengaluru Metro 42.30 Chennai Metro 27.36 Kochi Metro 13.30 Jaipur Metro 9.60 Kolkata Metro 27.39 Gurugram Metro 11.60 Mumbai Metro 11.40 Lucknow Metro 8.5 Hyderabad Metro 30.00 Total 399.35

The DULT is functions under Urban Development Department of Karnataka government. The Directorate is in general responsible is overseeing all the urban land transport initiatives in Urban also Local Planning Areas of Karnataka. And Karnataka is the only state in India to have an exclusive Directorate of Urban Land Transport (DULT). The directorate has been started in 2007 by the State Government close on the heels of National Urban Transport policy coming into force, to coordinates planning and implementation of urban transport matters in the State The CTTP was entrusted to be carried out by RITES Ltd. and was commissioned by Karnataka Urban Infrastructure Development & Finance Corporation (KUID&FC), a Government of Karnataka undertaking. RITES submitted the final report of CTTP during October 2007

Figure 6. Schematic map of Bengaluru Metro Phase 1 (Source: BMRCL)

3 METHODOLOGY

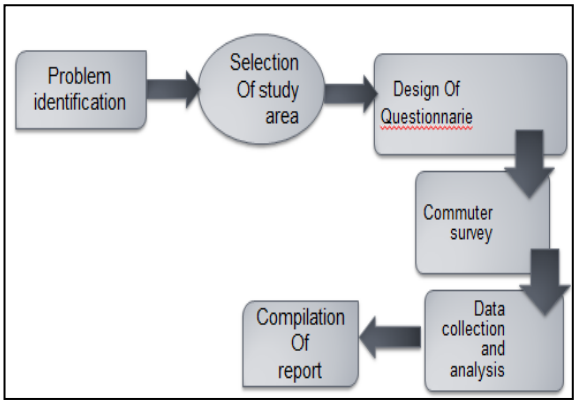

Figure 5. flow chart of Methodology adopted in the study

The methodology for analysing Last mile connectivity is as shown in Figure. The metro station were initially located on the GIS map and was verified during field survey using Survey123 for ArcGIS mobile app. For getting people effectively commuted from their home / destination to the nearest transit stop / station, the bus stops are desired to be located within 500m of walking distance from each metro station. To achieve this objective a 500m spatial buffer zone was created around the Metro stations using buffer tool available in ArcGIS software. This facilitates in identifying the Bus stops within 500m of metro transit stations. The spatial buffer zone of 500m created around the metro stations location was integrated into Survey123 mobile app. The field survey was then carried out using Survey123 for ArcGIS mobile app It is a simple form-centric data collection GIS app. Using ArcGIS organizational account of EMPRI "smart form" was developed and used for field survey. The field survey and data collection is started by downloading "Metro project" smart form developed by EMPRI. This smart form inside the mobile app contains the GIS layers like locations of Metro stations, 500m buffer zone and street maps around them which can be used in identifying nearest bus stops. Using random sampling, a total of 300 commuters were approached at the metro station for the survey. It gives result of more number of commuter coming from, age of commuter and gender , mode used and preferred

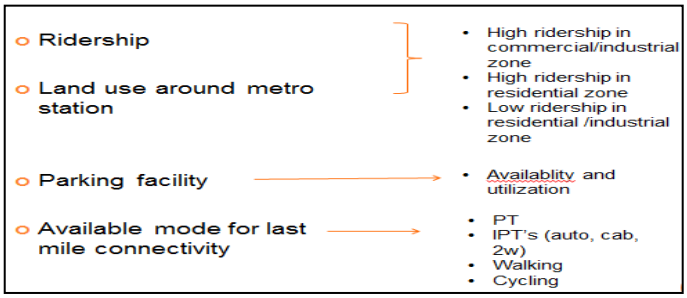

Figure 7. Parameters for selecting a metro station

3.1 Limitations of the study

- As the sample size for the survey was 300, it is not necessary that it truly represents the complete commuter population
- Few commuters have not given an accurate response, which affects the results of the study.
- Some commuters have not responded to all the questions and hence, those questionnaires were discarded.
- This study has been carried out for all type of transport. Because, it is also necessary to consider other modes of public transport and private transport which are operating in the vicinity of metro station bus stops ,the frequency of buses and number of trips by bmtc and occupancy of commuters of bmtc needs to be considered for detailed research in analysing time based density of buses operating in the congested routes

4 Design of Questionnaire

Questionnaires can be an effective means of measuring the behavior, attitudes, preferences, opinions and, intentions of relatively large numbers of subjects more cheaply and quickly than other methods. An important distinction is between openended and closedquestions. Questionnaires can be classified both, quantitative and qualitative method depending on the nature of questions. Specifically, answers obtained through closed-ended questions with multiple choice answer options are analyzed using quantitative methods and they may involve pie-charts, bar-charts and percentages. Answers obtained to open-ended questionnaire questions are analyzed using qualitative methods and they involve discussions and critical analyses without use of numbers and calculations The questionnaire was designed into four parts consisting of 12 questions; the first part covered the socio-economic profile of the commuters such as age, gender, occupation and the second part covered the mode of transport and usage characteristics followed by the third component-travel time of the each mode of the commuters and the fourth part consisting of general suggestions/concerns of the commuters.

a. Commuter Survey : The commuters were surveyed along each of the 24 stations of the North –South corridor of the Metro rail. A stratified random sample was adopted for the study. The survey was scheduled for duration of 12 hours between 8.00 a.m– 8.00.p.m. The commuters" perspectives were assessed through a structured questionnaire using specific factors related to transport sector

b. Data collection : The raw data can generate after the survey subjected to numerical coding and re-arrangement as per the requirement of the statistical software.

4.1 Quesionnaire format

Field Data collection using Survey 123 for ArcGIS

A. Metro commuter survey

Sl.No	Time of survey	To MS / From MS	Origin/ Destination	Purpose of trip	Frequency of trip	number of modes	Mode of commute				Travel time	Desired mode	comment /Remark
							Public	IPT	Private	Others			
				work	Daily		bus	auto	2w	walking			
				Study	Weekends		train	shared bike	4w	cycling			
				recreational	Occasionall		app based taxis						
				Social									
				healthcare									
				Others									

B. IPT Interview

AREA	DISTANCE	REASON FOR NOT SURVICING
JAYANAGAR		No return trip
		Short distance trip
		Not a good route
		Auto stand
		Others (specify)

5 Data Collection

A wide range of Geospatial tools and GIS based data collection mobile app are used in achieving the objectives of Last mile Connectivity analysis. Several GIS layers such as Metro rail route, Metro stations, Metro station Bus stops, Bus routes, Destinations, Road network, Route density are created progressively containing necessary attribute information of, origin point names, destination point names and eventually the Last mile connectivity is evaluated.

- ❖ Survey123 for ArcGIS is a simple form-centric data Analysing and Evaluating Last mile Connectivity collection GIS app.
- ❖ The field survey and data collection is started by downloading "Metro project" smart form developed by EMPRI.

Using ArcGIS organizational account of EMPRI "smart form" was developed and used for field survey. A Sample data collection of jayanagar metro station given below

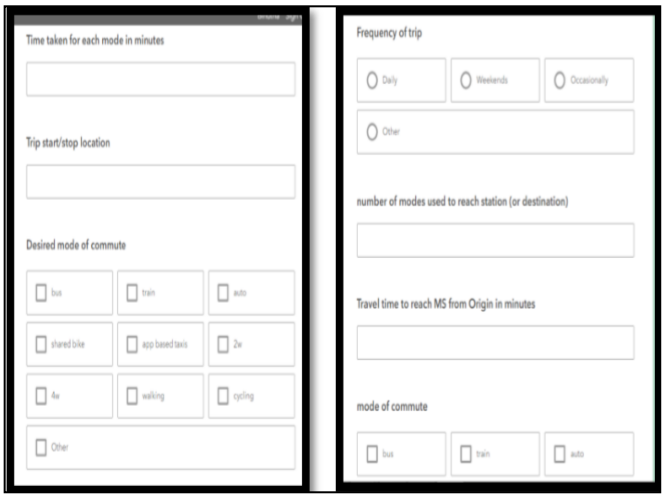

Figure 8 Survey123ArcGIS mobile app

SL.NO	Origin/Destination	T.T	E.M	Destination	AGE	G	x	y
1	Jayanagar 1st block	10	10	mantri square	23	M	77.6	12.9
2	Jayanagar 1st block	5	5	peenya	65	F	77.6	12.9
3	Jayanagar 1st block	30	10	lal bagh MS	34	M	77.6	12.9
4	Jayanagar 1st block	5	10	mantri square	18	M	77.6	12.9
5	Jayanagar 2nd block	20	7	rr nagar	45	M	77.6	12.9
6	Jayanagar 3rd block	5	5	mantri square	18	F	77.6	12.9
7	Jayanagar 3rd block	15	15	mantri square	26	F	77.6	12.9
8	Jayanagar 3rd block	5	5	mantri square	57	F	77.6	12.9
9	Jayanagar 3rd block	10	5	kanakapura	21	M	77.6	12.9
10	Jayanagar 3rd block	10	35	mantri square	24	M	77.6	12.9
11	Jayanagar 3rd block	7	10	jallahali	32	F	77.6	12.9
12	Jayanagar 3rd block	5	15	mantri square	31	M	77.6	12.9
13	Jayanagar 3rd block	5	5	yelchenahalli	28	F	77.6	12.9
14	Jayanagar 3rd block	5	10	baiyappanahalli	60	M	77.6	12.9
15	Jayanagar 3rd block	15	15	KR MARKET	17	F	77.6	12.9
16	Jayanagar 3rd block	10	15	koramangala	16	M	77.6	12.9
17	Jayanagar 3rd block	10	5	majestic	16	F	77.6	12.9

Figure 9 Sample Data collected using survey123 ArcGIS

6 Result and Analysis

A survey which impacts of the metro rail system on the commuters last mile connectivity along the north south corridor of the metro rail was undertaken. Stratified random samples of 300 commuters were surveyed in jayanagar stations of the metro rail. The metro station were initially located on the GIS map and was verified during field survey using Survey123 for ArcGIS mobile app. For getting people effectively commuted from their home / destination to the nearest transit stop / station, the bus stops are desired to be located within 500m of walking distance from metro station. To achieve this objective a 500m spatial buffer zone was created around the Metro stations using buffer tool available in ArcGIS software. This facilitates in identifying the Bus stops And Other Modes within 500m of metro transit stations

The EMPRI field surveyor walked up to the nearest bus stops from each metro station and the mobile app displayed whether the bus stops fall within the range of 500m or not. This mobile app, if working offline, the completed survey forms will be saved locally. When mobile is connected with internet data service, the survey details is submitted back to ArcGIS Server. (as shown in the figure This information is retrieved in the GIS server of the mobile app at EMPRI and re-validated for location with respect to 500m buffer zone of metro station. Finally the number of bus stops in the 500m range of metro stations were finalised and used for further exploration.Origin to destination via metro station connecting bus stops And Other Modes. The bus route details against respective bus route numbers can be obtained from BMTC website (www.mybmtc.com). Identifications Of Spatial Locations Of Metro Stations In Jayanagar Green Line Corridor The metro stations was identified in the Phase-2, Green line stretch of north south corridor. A jayanagara metro station is selected it has large number of commuter for work purpose ,educational, ,ocasinally ,recreational, social purpose it has high ridership of the commuter to metro station Buffer Zone Of 500m From Metro Stations To identify accessible Bus stops within 500m walking distance of commuters, a GIS based field survey was carried out by EMPRI. To carry out this survey on GIS platform Survey123 for ArcGIS mobile app – smart form was used. Various details such as name of the surveyor, bus stop name, GPS location, confirmation of bus stop lying in 500m buffer zone, photographs of the bus stop and surroundings and other relevant information is collected through the mobile app and retrieved in GIS server. Result which obtained after data collection is given below.

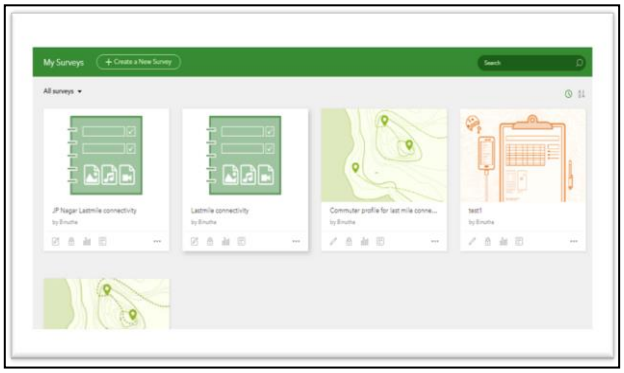

Figure 10 Survey 123 Arc GIS App form

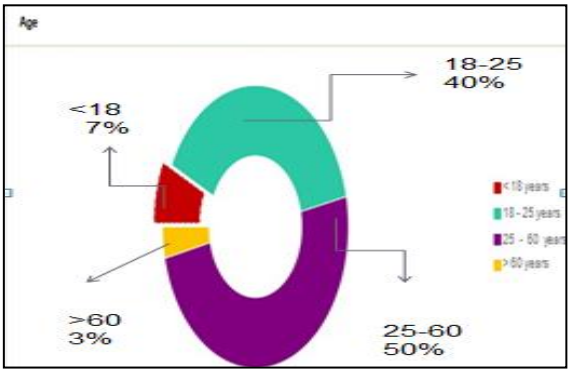

Figure 14. Age of commuter in %

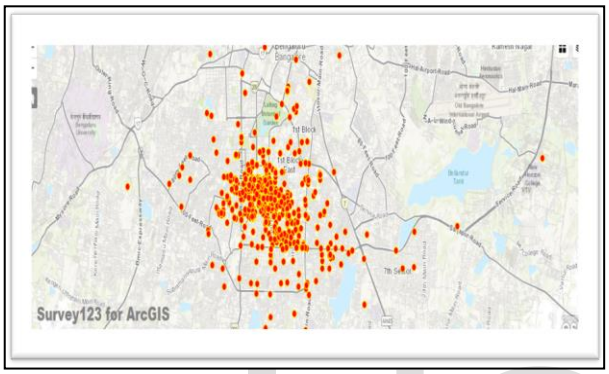

Figure 11.Commuter profile access to metro station

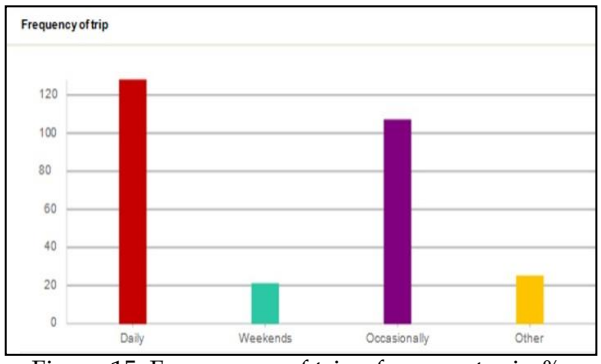

Figure 15 .Frequency of trip of commuter in %

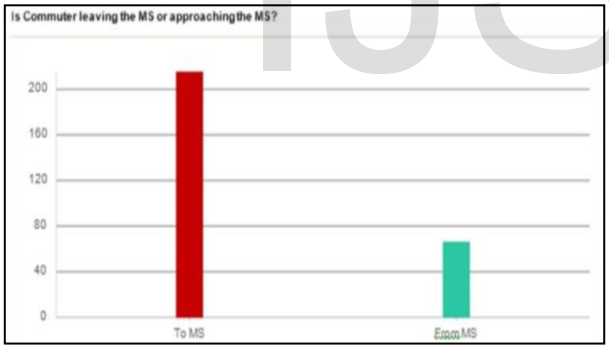

Figure 12.To Ms -76% and From Ms -24%

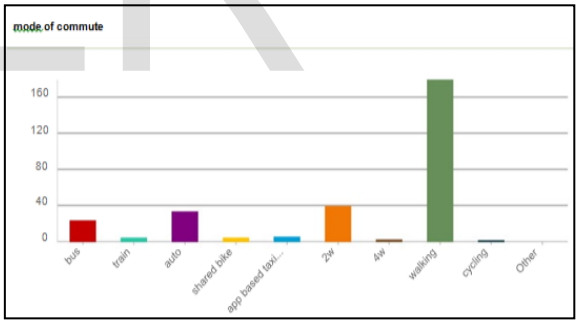

Figure 16. Mode of trip of commuter in %

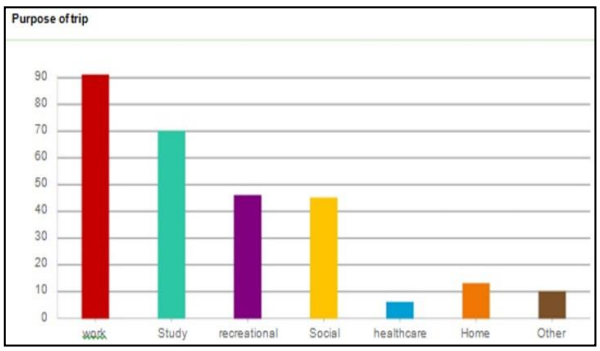

Figure 13.Purpose of trip of commuter in %

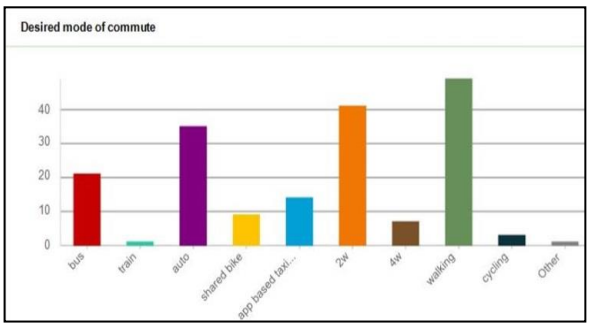

Figure 17. Desired mode of trip of commuter in %

The Last mile connectivity is evaluated based on various parameters such as the number of destinations which is connected to metro station by buses ,two /four wheelers, the total distance covered, and the density of buses travelling via different sectors .The above evaluations are carried out on a spatial analysis and explained.This evaluates the ease with which passengers can access metro services and commute to different parts of the city timely and efficiently. The outermost destination covered by BMTC services and feeder service has to be improved by providing more number of buses to last mile destination for the different sectors

7 CONCLUSION

- Commuters preference given to mass transit system has increased ever since its launch but traffic congestion has not reduced significantly.
- Inspite of increase in commuter population in metro, Metro has emerged as safe mode of transport, but still commuters continue with unsafe modes of transport due to limited connectivity of the metro rail.
- The Bengaluru Metro on the green line corridor has good accessibility to bus stops within walkable distance of 500m around metro stations.
- Also need a improvement of shuttle services. Jayanagara line Metro station bus stops connect to several last mile destinations spread across the city and study shows well connectivity to destinations in the north south direction.
- Wards connectivity analysis carried out using GIS spatial analysis tools reveal that the "namma metro" services are well connected to various direction Repetitive BMTC buses operating from various last mile destinations converging towards a common route and shuttling to central bus stations can be operated by use of bus terminals / Metro station bus stops as end point and avoid traffic congestions inside central city areas

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