Integration of BMRCL and BMTC

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Integration of BMRCL and BMTC

1. **Route Integration**
2. **Infrastructure Integration**
3. **Institutional Integration**

Final Report

Submitted by

Center for Study of Science, Technology and Policy

To

Bengaluru Metropolitan Transport Corporation, Government of Karnataka

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Background to the Study

About Bengaluru

Bengaluru, the capital of Karnataka, is one of the fastest growing metropolitan cities in India. It is home to major information technology companies, public sector undertakings and major educational and research institutions. The city of Bengaluru has an area of 741 sq. km. with a population of 8.52 million (Census of India 2011). In 2001, Bengaluru's area was 531 sq. km. and population was 5.10 million. Bengaluru has experienced rapid population and urban growth during the last decade (2001-2011).

With rapid urbanisation and population growth, there is a huge demand for improving urban infrastructure, of which public transport is critical. In Bengaluru, as per a study conducted by the Directorate of Urban Land Transport, 27% of all trips are by public transport, 31% of the trips are by two-wheelers and cars, 35% of the trips are by non-motorised transport (walk and bicycle) and 7% by intermediate public transport (autos and taxis) (DULT 2010).

About BMTC

Bengaluru Metropolitan Transport Corporation (BMTC) provides public transport bus services to Bengaluru metropolitan region. BMTC tries to keep pace with the changing urban mobility demand by operating various services such as chartered services, Vayu-Vajra services, Vajra services and ordinary services.

BMTC operates 6,383 buses and carries approximately 5.02 million passengers daily, generating a revenue of INR 5.76 crore per day (BMTC 2017). The gross revenue for BMTC in 2016-17 was INR 2,106 crore, of which traffic revenue contributed to INR 1,770 crore (~84%), while non-traffic contributed to INR 336 crore (16%).

About BMRCL

Bangalore Metro Rail Corporation Limited provides metro rail mass transport services to the city of Bengaluru. Phase I of Metro operations covers the East-West corridor – 18.10 km, and the North-South corridor – 24.20 km. Commercial operations from MG Road to Baiyapanahalli began in October 2011, with additional stretches commencing operations subsequently. The complete Phase I commenced operations in June 2017. Daily ridership on Bangalore Metro regularly exceeds 4 lakh passengers with daily revenue of approximately INR 1.3 crores. Phase II of Bangalore Metro construction is currently underway and is expected to be completed by 2020-21.

While it is good that Bengaluru has two mass transport agencies, there is a need for integration between them. Integration between BMTC and BMRCL would lead to greater mode share for public transport, reduced congestion and lesser pollution levels. This study focuses on three aspects of integration – route, infrastructure and institutional between BMTC and BMRCL.

In order to carry out the study, Government of Karnataka has engaged Center for Study of Science, Technology and Policy (CSTEP) as a technical research institution. Karnataka Evaluation Authority (KEA) has been appointed as the coordinating and nodal agency to ensure timely completion of this work.

Acknowledgement

Center for Study of Science, Technology and Policy expresses deep gratitude to Government of Karnataka for its support in conducting this study.

We would like to thank Bangalore Metro Rail Corporation (BMRCL) officials Shri. Pradeep Singh Kharola, Ex-MD, and Shri. U. A. Vasanth Rao, GM, Finance (Taxation and Resource) for their support throughout this project, grating permission to conduct required surveys at the Metro stations and sharing the required data.

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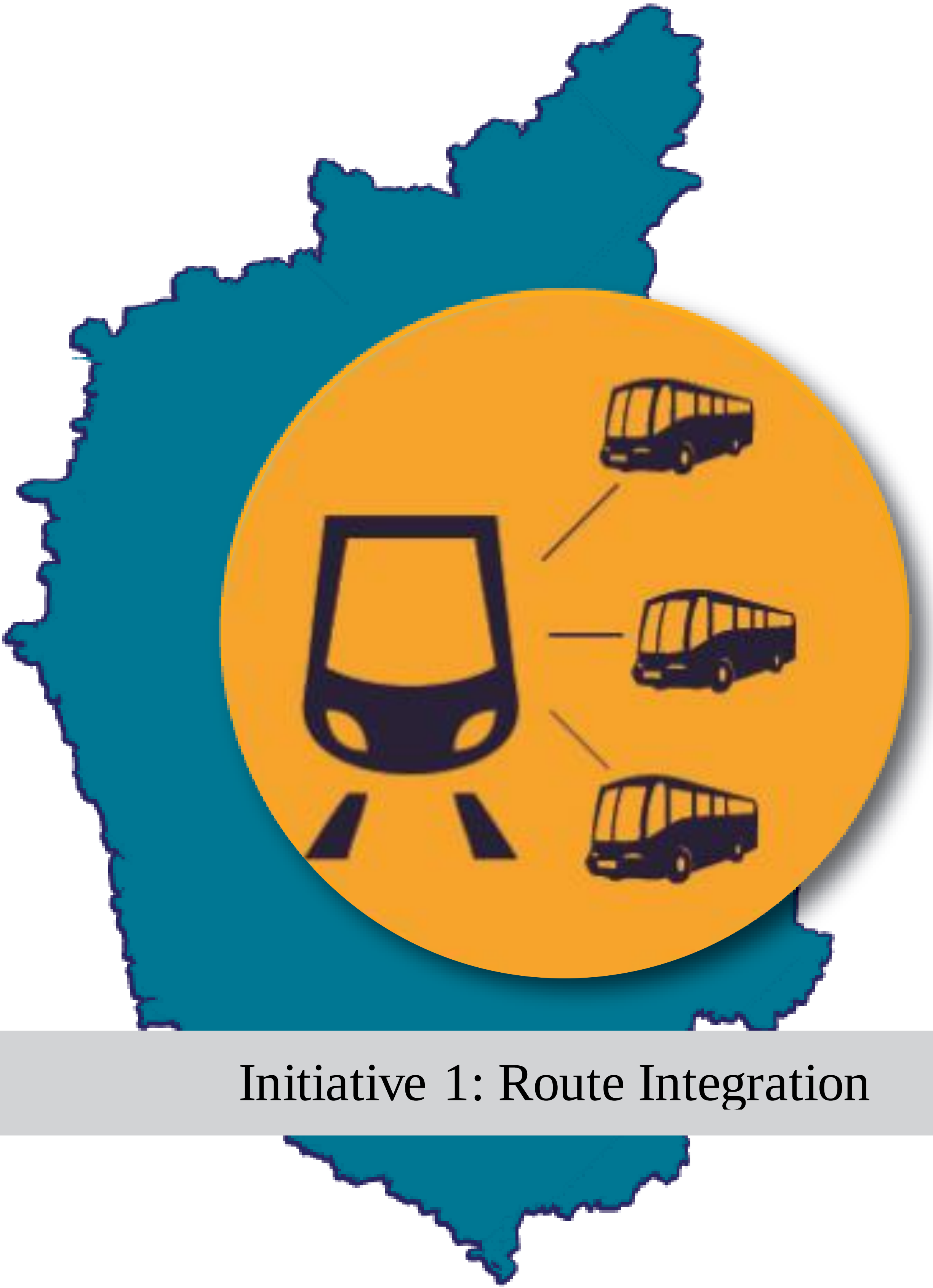

Initiative 1: Route Integration

Initiative 1: Route Integration

Abbreviations and Acronyms

Abbreviations	Full Form
API	Application Programme Interface
BBMP	Bruhat Bengaluru Mahanagara Palike
BMRCL	Bangalore Metro Rail Corporation Limited
BMTC	Bengaluru Metropolitan Transport Corporation
BS	Bus Stand
CPKM	Cost Per Kilometre
DCM	Discrete Choice Model
EPKM	Earning Per Kilometre
ETM	Electronic Ticketing Machine
GIS	Geographical Information System
HH	Household
MS	Metro Station
O-D	Origin-Destination
ODK	Open Data Kit
OSM	Open Street Map
RMP	Revised Master Plan
RP	Revealed Preference
RTO	Regional Transport Office
SP	Stated Preference
SRS	Simple Random Sampling
TTMC	Traffic and Transit Management Centre

Executive Summary

Bengaluru Metropolitan Transport Corporation (BMTC) and Bangalore Metro Rail Corporation Limited (BMRCL) are the primary public transport service providers in Bengaluru, which aim to provide safe, reliable, clean and affordable transportation. To achieve this aim and to make public transport the preferred mode of transport in Bengaluru, it is important to integrate public transport services.

In this context, Government of Karnataka has engaged Center for Study of Science, Technology and Policy (CSTEP) as a technical research institution to suggest ways for the integration of BMRCL and BMTC. This study focuses on route integration, which involves estimating the willingness of Metro passengers to use the feeder bus service and identifying appropriate Metro feeder routes.

In this study, potential feeder routes were identified based on a Metro passenger opinion survey. Stratified Random Sampling technique was used to arrive at required sample size. This survey was conducted at 12 Metro stations and 2,431 respondents were interviewed. Discrete Choice Modelling technique was used to estimate the probability of shift to Metro feeder service.

The survey captured the current mode of transport and the preferred mode of transport using the revealed-preference and stated-preference survey techniques. The willingness to shift to Metro feeder service was captured for commuter trips from origin to the boarding Metro station (access trips) and also for trips from the alighting Metro station to the destination (egress trips). For the stations where there is a maximum probability of shift, potential feeder routes were identified considering the respondents' trip patterns, existing Metro feeders and major activity centres.

For access trips, the maximum willingness to shift to feeder services was observed at Goraguntepalya, S. V. Road, Mysore Road and Indiranagar Metro stations. Similarly, for egress trips, the maximum willingness to shift to feeder services was observed at Indiranagar and S. V. Road Metro stations. Based on the analysis the study proposes feasible feeder routes at four Metro stations. These routes cover areas which are not well served with BMTC services.

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1. Introduction

BMRCL and BMTC are the two major public transport service providers for Bengaluru. Route integration is needed to increase the overall public transport mode share of the city.

One way by which this could be achieved is BMTC providing feeder service to Metro. For this, it is essential to understand the passenger demand for feeder and travel patterns of Metro passengers. This study estimates the willingness of Metro passengers to shift to the BMTC feeder bus service for first and last mile connectivity and identification of feasible feeder routes.

2. Log Frame / Theory of Change / Programme Theory

2.1. Logic of Route Integration

After the commencement of Bengaluru Metro Reach 1 (M. G. Road to Baiyappanahalli) in 2011, BMTC started a few feeder bus services. BMTC introduced additional feeder services with the completion of Phase I (Citizen Matters 2017). The current feeder services connect areas with nearby Metro stations as well as between Metro stations. These services are incurring losses due to low usage and high operational cost. There is a need to examine Metro users' travel patterns to propose new feeder routes. This study aims at identifying the feasible Metro feeder routes for Phase I Metro stations.

	Intervention Logic	Verifiable Indicators of Achievement	Sources and Means of Verification	Assumptions
Overall Objectives	*What are the overall broader objectives to which the activity will contribute?* To integrate the two public transport services of Bengaluru, bus and Metro, for better connectivity	*What are the key indicators related to the overall objectives?* Achieving first and last mile connectivity for Metro by BMTC service	*What are the sources of information for these indicators?* Metro passenger opinion survey	*NA*
Specific Objectives	*What specific objectives is the activity intended to achieve to contribute to the overall objectives?* • To estimate willingness of Metro users to shift to BMTC's Metro feeder service • To identify the feasible feeder routes for Phase I Metro corridor	*Which indicators clearly show that the objective of the activity has been achieved?* Implementation of suggested Metro feeder routes by the competent authority	*What are the sources of information that exist or can be collected? What are the methods required to get this information?* Secondary data collection: • Ridership details from BMRCL Primary data collection: • Metro passenger opinion survey	*Which factors and conditions outside the PI's responsibility are necessary to achieve that objective? (external conditions)* *Which risks should be taken into consideration?* • Permission of the competent authority to conduct the survey • Willingness of competent authority to implement the suggested Metro feeder routes
Expected results	*The results are the outputs envisaged to achieve the specific objective.* *What are the expected results? (enumerate them)* • Willingness of the Metro users to shift to the BMTC feeder service	*What are the indicators to measure whether and to what extent the activity achieves the expected results?*	*What are the sources of information for these indicators?* Site visits	*What external conditions must be met to obtain the expected results on schedule?* • Willingness of competent authority to implement the suggestions as per the report

	• Feasible Metro feeder routes for the select Metro station	Completion of Metro passenger survey at select Metro stations		• Schedule of survey and bus schedule as decided by competent authority
Activities	*What are the key activities to be carried out and in what sequence in order to produce the expected results?* *(group the activities by result)* 1. Secondary data collection for Metro ridership 2. Identifying Metro stations for primary survey 3. Preparation of questionnaire and arriving at sample size for primary survey 4. Conducting Metro passenger opinion survey 5. Formulating Origin-Destination (O-D) matrix 6. Identifying potential activity centres 7. Identifying of feasible Metro feeder routes 8. Secondary data collection of existing Metro feeder routes characteristics 9. Validation of feasible Metro feeder routes through site visits 10. Suggesting feasible feeder routes.	***Means:*** *What are the means required to implement these activities, e. g. personnel, training, studies, etc.* • Urban planning experts • Transport planning experts • Training for conducting primary survey	*What are the sources of information about action progress?* • Site visits • Interaction with competent authority	*What pre-conditions are required before the action starts?* • Acceptance by the authority for the suggested changes • Plan for actual implementation and timely completion

3. Progress Review

This section describes the existing feeder bus route characteristics.

3.1. Scope of Existing Feeder Bus Service

BMTC initiated the Metro feeder service after the launch of the first reach of Metro from MG Road to Baiyappanahalli in 2011. BMTC operated about 24 feeder routes with 60 buses deployed at six Metro stations (Sastry 2011). As BMRCL started operating the entire Phase I Metro corridor, BMTC made arrangements to introduce more services based on the feedback from the public through its website, social media and other sources. Thus, BMTC started operating 29 Metro feeder bus routes with 205 schedules from June 2017 (Kumar 2017). As on February 2018, BMTC runs 793 schedules for 23 feeder routes. The list of operational feeder routes is given in Annexure 1.

3.2. Performance of Existing Feeder Services Based on Baseline Data

The existing Metro feeder routes are running with an average route length of 15 km and frequency of about 10-20 minutes. As of June 2017, 1,918 feeder trips (out of 3,142) are running for the North-South Metro corridor. There are seven routes running from S. V. Road Metro station to different parts of the city including Whitefield, Marathahalli, Hoodi, Ramamurthynagara, Koramanagala etc.(Citizen Matters 2017). The spending per kilometre for all BMTC feeder services for the East-West Metro corridor from October 2016 to March 2017 was INR 13,129 and the earning was INR 7,464 per km (Madhavan 2017).

4. Problem Statement

To understand the willingness of Metro users to shift to feeder services and also to propose new feeder routes to improve connectivity.

4.1. Gaps/Weaknesses in Existing Feeder Service

As mentioned in the previous section, BMTC is unable to meet the operational expenses of the feeder services. On the other hand, even if the Metro ridership is observed approaching 3.5 lakhs per day (The Hindu 2017), the first and last mile connectivity seems to be a matter of concern for the metro users; for instance, the auto fare and parking fee increase the expense of the total travel cost by Metro (Bandyopadhyay 2017).

A few studies suggest Metro feeder routes should serve a short distance (4 to 6 km), with a high frequency of 5 to 10 minutes or a maximum of 15 minutes (WRI 2014), (NCR Transport Department 2014), (Urban Mass Transit Company Limited 2014). However, the average route length of BMTC Metro feeder routes is 13.2 km with a maximum route length of 28 km and a minimum of 4.5 km. As per the discussion with BMTC officials, the shorter trip lengths increase the CPKM. Hence preference is given to longer trip lengths, that is, above 15 km. This contradiction poses a challenge to arrive at an optimal feeder route length.

The other challenges faced for Metro–bus route integration are stated below:

- Lack of potential ridership for feeder on account of limited Metro ridership
- Lack of information on passenger demand for feeder services
- Lack of coordination between the two agencies (in terms of frequency and time)

Evaluation Question

What are the feasible BMTC feeder routes for Phase I Metro corridor?

This study identifies potential feeder routes based on trip-generating and trip-attracting areas. This will be further refined/modified according to the on-ground scenario (such as road width along the route, activity centres along the route etc.) in consultation with stakeholders.

5. Objective and Issues of Evaluation

Objective

To propose feeder routes for Phase I Metro corridor

Scope

Target population: The target population for this study are the Metro users.

Geographical coverage: Influence area based on origin and destination of Metro users

6. Evaluation Design

6.1. Information Sources:

The required data and information need to be gathered by primary as well as secondary sources. The secondary data was collected from the following agencies:

1. Bengaluru Metropolitan Transport Corporation (BMTC) – List and details of existing feeder routes
2. Bangalore Metro Rail Corporation Limited (BMRCL) – Station-wise Metro ridership data
3. Census 2011 – Ward-wise population and population density
4. RMP 2015 – Land use along the Phase I Metro corridor

A gap analysis between the data requirements for the study and the data available from the secondary sources was carried out to decide on the type of survey to be undertaken. Based on the same, the following primary survey was planned.

Metro Passenger Opinion Survey: This survey was conducted along Phase I Metro stations, to gather information regarding socio–economic and travel characteristics of Metro users. This survey also captured Metro users' willingness to shift to the BMTC Metro feeder service.

7. Evaluation Methodology

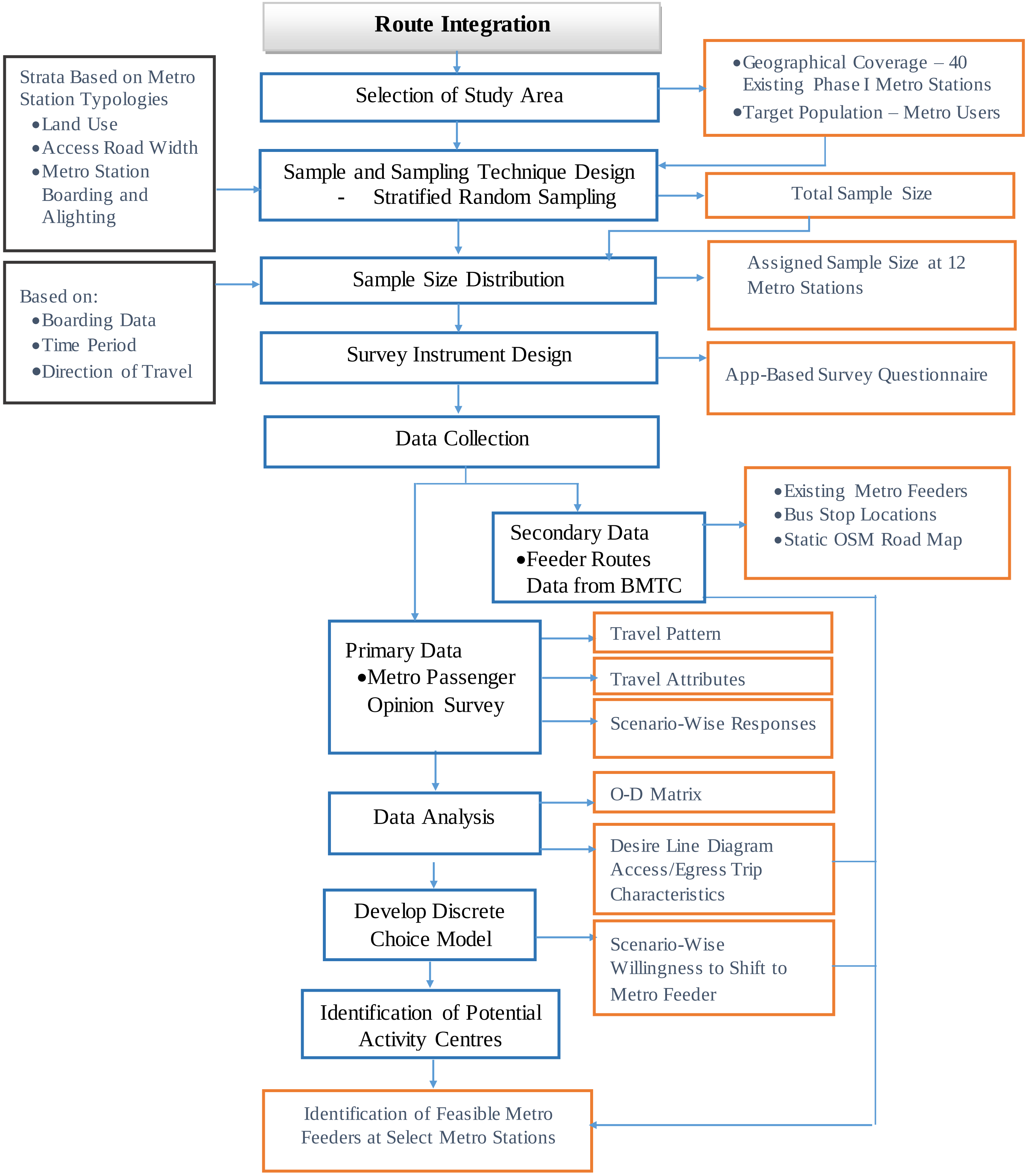

Figure 1: Process of Metro - bus route integration

6.2. Sample and Sampling Design

6.2.1. Stratified Random Sampling

A stratified random sampling technique was used to arrive at an appropriate sample size at each Metro station. The existing 40 Metro stations were stratified based on the parameters listed below:

1. Existing land use within a radius of 500 metres around the Metro station
2. Access road width
3. Boarding data

The six station typologies are described below:

Type 1 – Transport hubs which are connected with other public transport modes in the vicinity

Type 2 – Metro stations which are located in predominantly residential areas, with high boarding and access road width in the range of 30 to 80 metres

Type 3 – Metro stations which are located in predominantly non–residential areas, with high boarding and access road width of 30–50 metres

Type 4 – Metro stations which are located in predominantly residential areas, with high boarding and access road width of 12–30 metres

Type 5A – Metro stations which are located in predominantly residential areas, with low boarding and access road width of 30–80 metres

Type 5B - Metro stations which are located in areas of mixed-land use, with low boarding and access road width of 30–80 metres

Type 6 – Metro stations which are located in predominantly residential areas, with low boarding and access road width of 12–30 metres

Table 1: Metro station typologies

Station Name	Predominant Land Use				Access Road Width			Boarding Data		Type	
	Residential	Commercial/ Public–Semi-Public	Industrial	Transport	50 m – 80 m	30 m – 50 m	12 m – 30 m	HB	LB		
Majestic										1	Transport Hubs
Yeshwanthpur											
Baiyappanahalli											
City Railway Station											
Nagasandra										2	High Residential, 30-80 m Road, HB
Dasarahalli											
Yelachenahalli											
Rajajinagar											
Banashankari											
J. P. Nagar											
Vijayanagar											
Trinity											
Sandal Soap Factory										3	Non-Residential, 30-50 m Road, HB
M. G.Road		ü									
Mysore Road											
National College										4	Residential, 12-30 m Road, HB
Southend Circle											
R. V. Road											
Indiranagar											
Sampige Road											
Vidhana Soudha		ü									
Sir M. Visveshwaraya		ü									

Station Name	Predominant Land Use				Access Road Width			Boarding Data		Type	
	Residential	Commercial/ Public-Semi-Public	Industrial	Transport	50 m – 80 m	30 m – 50 m	12 m – 30 m	HB	LB		
Hosahalli										5 A & 5 B	Residential, 30-80 m Road, LB
Deepanjali Nagar											
Mahalakshmi											
Halasuru											
Attiguppe											
Jalahalli											Mixed Land Use, 30-80 m Road, LB
Peenya Industry											
Peenya											
Goraguntepalya											
Cubbon Park		ü									
S. V. Road											
Chickpet		ü								6	Residential, 12-30 m Road, LB
K.R.Market		ü									
Kuvempu Road											
Srirampura											
Jayanagar											
Lalbagh											
Magadi Road											

Legend:

- Residential
- Public/Semi Public
- Commercial
- Green
- Industrial
- Transport
- 50-80 m Wide Road
- 30-50 m Wide Road
- 12-30 m Wide Road
- High Boarding
- Low Boarding
- ü Other Additional Land Use (Defined by Colour)

Twelve representative Metro stations from each strata were selected for further study, as shown in Table 2: Metro passenger opinion survey locations and sample size For each of the strata, the total population was the sum of the boarding passengers' at all Metro stations falling under it. Simple Random Sampling (SRS) technique was used to estimate the statistically relevant sample size for each strata. Further details of the sampling technique can be found in Annexure 2.

Table 2: Metro passenger opinion survey locations and sample size

Sr. No.	Metro Station	Typology	Total Sample Size
1	Majestic	1	173
2	Baiyappanahalli	1	209
3	Nagasandra	2	160
4	Banashankari	2	222
5	Mysore Road	3	172
6	M. G. Road	3	210
7	Indiranagar	4	251
8	Vidhana Soudha	4	153
9	S. V. Road	5	200
10	Attiguppe	5	181
11	Kuvempu Road	6	171
12	Goraguntepalya	5	210
TOTAL			**2,312**

After arriving at an appropriate sample size, the sample to be collected at each Metro station was distributed temporally as well as directionally. The temporal distribution was done for three time periods in a day, morning peak (8 AM to 11 AM), evening peak (5 PM to 8 PM) and off-peak (2 PM to 4 PM). The directional distribution was based on the location and type of the Metro station. For example, at Majestic Metro station, Metro passengers travelling in all the four directions were surveyed. Similarly, for terminal stations like Baiyappanahalli, Metro passengers travelling towards Mysore Road were surveyed. A detailed sample distribution is shown in Annexure 3.

6.3. Types of Data Collected from Various Sources

6.3.1. Secondary Data:

1. Station-wise boarding and alighting Metro passenger data
2. Existing land use data for Bengaluru

3. Existing feeder route data from BMTC
4. BMTC bus stop locations
5. Major activity centres around select Metro stations

6.3.2. Primary Data:

Metro Passengers Opinion Survey

- Travel pattern of Metro passengers
    - Origin-destination
    - Mode of travel for first and last mile connectivity – walking, two wheeler, car, cab, auto and bus
- Scenario-wise willingness to shift to Metro feeder for first and last mile

6.4. Instruments for data collection

6.4.1. Secondary Sources

A data requirement template was shared with the concerned agencies. The data collection template is given in Annexure 4.

6.4.2. Primary Surveys

For the primary data collection, a structured survey questionnaire was used to capture the required data. The questionnaire for this survey is given in Annexure 5. Open Data Kit (ODK), an Android-based mobile app, was used to collect the primary data[1].

Metro passenger opinion survey questionnaire comprised the following sections:

1. Passenger information (socio–economic profile)
2. Travel information
3. Scenarios for mode choice

6.5. Protocols for Data Collection and Ethics Followed

Secondary data for the current study was collected from BMTC and BMRCL. For the primary field survey at Metro stations, permission letters from BMRCL and BMTC were taken for conducting surveys within the Metro stations.

[1] Open Data Kit. 2018. 'Open Data Kit'. Home. 2018. https://opendatakit.org/

8. Data Collection and Analysis

8.1. Data collection

8.1.1. Primary Data

After the structured questionnaire was prepared, it was discussed with the stakeholders and revised to incorporate the suggested changes. This questionnaire was then tested by conducting a pilot survey at select Metro stations. This pilot survey revealed that the questionnaire took six minutes for a full response, whereas the frequency of the Metro was five minutes. Hence, the questionnaire was redesigned to capture the required data in less than five minutes.

This survey instrument was administered at 12 Metro stations, and 2,430 samples were collected. The primary survey attempted to collect responses from an equal number of men and women respondents.

The entire primary survey was carried out across a span of two working weeks. The survey was carried for a time period of 12 hours (8:00 AM-8:00 PM) at all the select Metro locations, covering morning peak, off-peak and evening peak on a normal working day. The survey locations are given in Table 2. The locations were duly identified based on the Metro station typology. The survey was carried out using ODK suite, which replaced paper-based forms. Specially trained field investigators and enumerators under the close guidance of supervisory staff were utilised for this purpose. All the data thus collected was compiled and subjected to a thorough verification and analysis.

The data from the primary survey was extracted in an Excel format. This data was then checked for completeness, invalid samples and data entry errors. After all these filters, a clean data set was considered for analysis.

8.1.2. Secondary Data

The Metro-feeder data received from BMTC was considered to understand the existing feeder route characteristics (origin, destination, route length and Metro stations covered). This data was also used to understand the underserved Metro stations and to avoid suggesting overlapping feeder routes.

8.1.3. Data Digitisation

Data digitisation consisted of plotting origin and destination of respondents based on landmarks and locations collected during Metro passenger opinion survey. To achieve this, the Geographical Information System (GIS) location—latitude and longitude of the passenger—was required. This was accomplished by writing a script in Python (a programming language), which fetches each survey respondent's landmark from the collected dataset and uses the Google Maps Application Programming Interface (API) to retrieve the GIS information. The script then filters out the latitude and longitude from the resultant GIS information and places the resultant latitude and longitude in the corresponding respondent's opinion in the dataset.

8.2. Data Analysis

A detailed socio-economic profile of respondents was prepared (Annexure 6). Out of 2,432 respondents interviewed, 54% were male and 46% were female. 49% of the Metro users were in the age group of 19–30 and about 42% of Metro users were in the age group of 31–50. 53% of the respondents had a monthly HH income within a range of INR 20K–50K. 70% respondents were from the working class; out of the total working respondents, 77% were on their daily work trips.

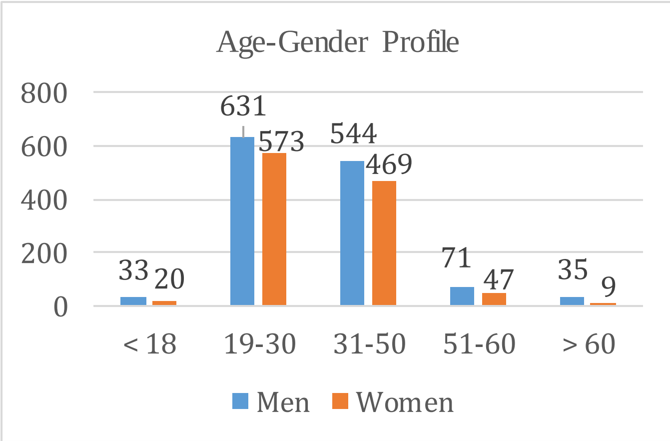

Figure 2: Age-gender profile of respondents

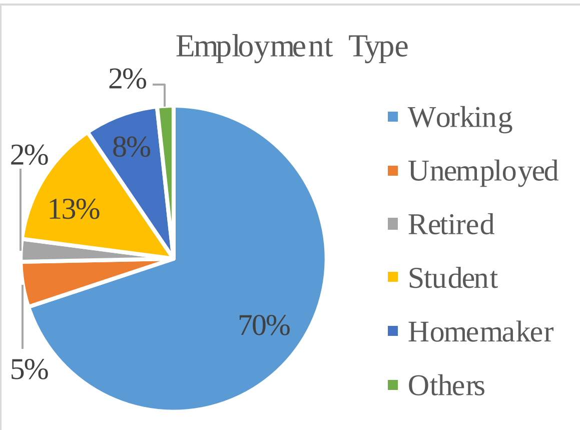

Figure 3: Employment profile of respondents

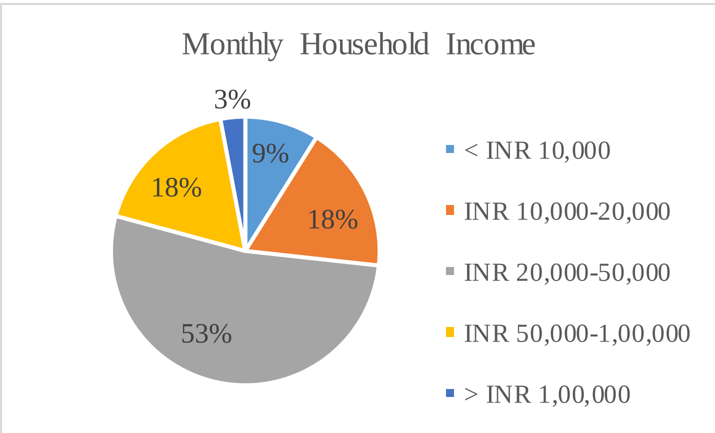

Figure 4: Income profile of respondents

8.2.1. Travel Pattern of the Respondents

Purpose and Frequency of Travel

The purpose and frequency of travel of Metro passengers are presented in Figure 5 and Figure 6. Of the total trips, 68% were for work trips, followed by educational trips (12%). 68% of the respondents were on their daily trips, followed by 18% who travelled weekly.

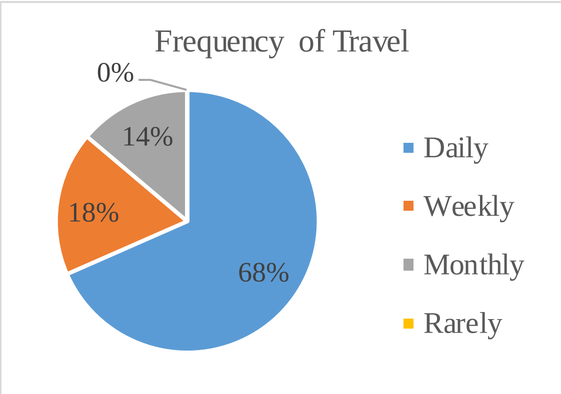

Figure 5: Frequency of travel

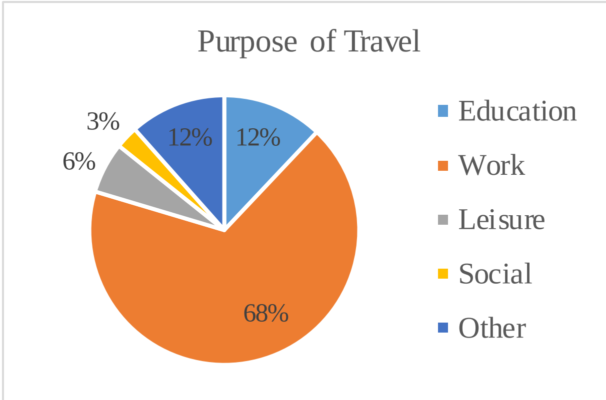

Figure 6: Purpose of travel

8.2.2. Formation of Origin - Destination Matrix

From the survey, each respondent's access (from origin to boarding Metro station) and egress (from alighting Metro station to destination) trip was plotted. All the origins and destinations of the survey respondents were assigned to the corresponding wards and plotted to understand the travel patterns of the respondents. Figure 7 represents Metro Phase I corridors (East–West & North–South), Metro stations, ward boundary and number, access trips and egress trips. The access and egress trips were classified based on the number of trips between ward and Metro station. This desire line diagram, served as an input for proposing new Metro feeder routes.

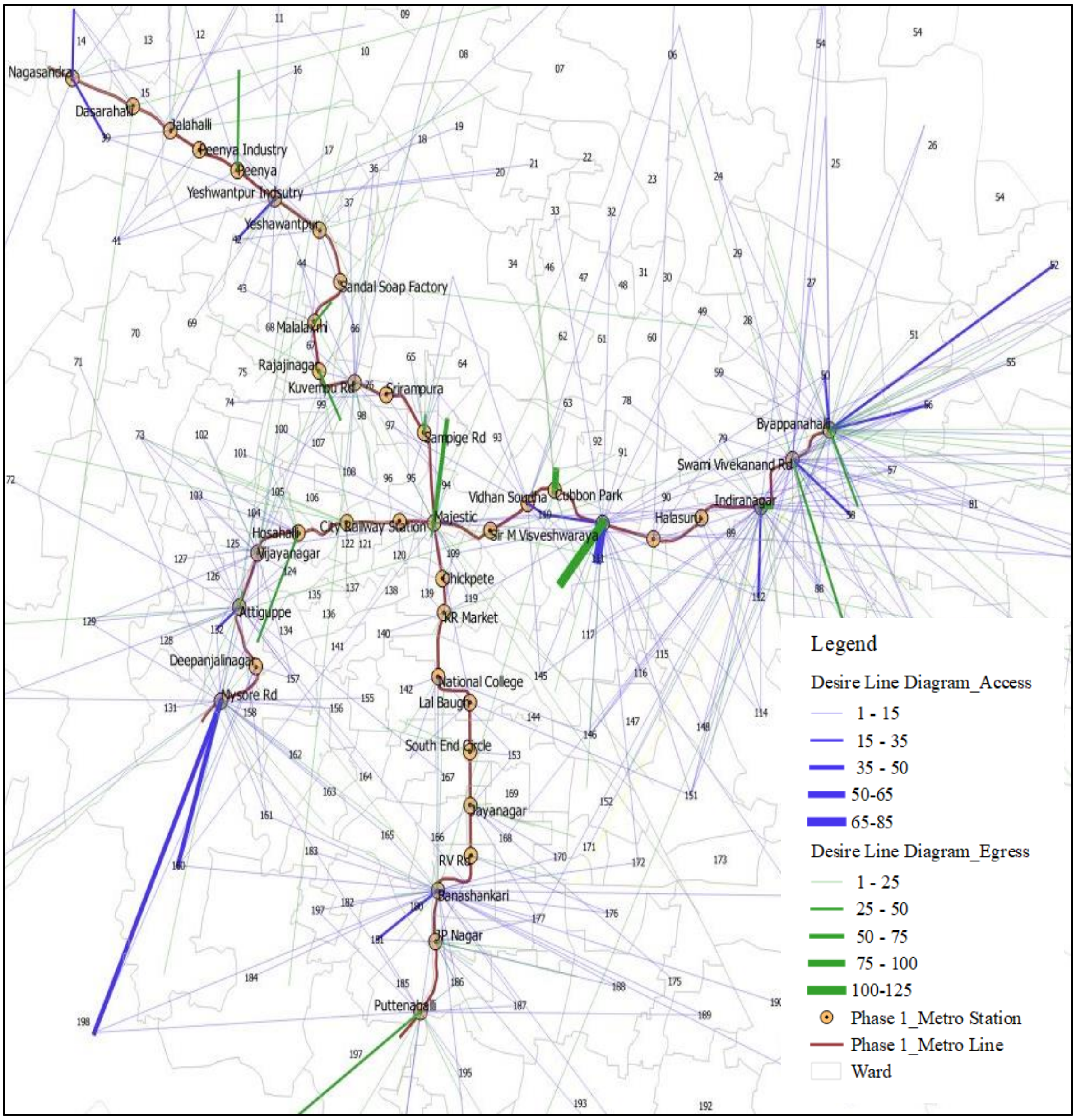

Figure 7: Desire line diagram

8.2.3. Access and Egress Mode

The survey showed that almost 47% access trips and 57% egress trips of the respondents were on foot. Bus was the second preferred mode for access (18%) and egress (15%). Table 3 shows the access and egress mode share.

Table 3: Access and egress mode share

Mode of Travel	Access		Egress	
	Count	Percentage	Count	Percentage
Walking	1,131	47%	1,380	57%
Car	82	3%	19	1%
Two Wheeler	419	17%	190	8%
Auto	279	11%	346	14%
Bus	436	18%	376	15%
Cab/Taxi	75	3%	102	4%
Share Taxi	8	0%	16	1%
TOTAL	**2,430**	**100%**	**2,428**	**100%**

8.2.4. Access and Egress Distance

26% of the access trips and 33% of the egress trips of the respondents are less than 0.5 km, as shown in Table 4. The maximum share of access trips (37%) and egress trips (36%) fall in the rage of 0.5-2 km.

Table 4: Access and egress distance

Distance	Access		Egress	
	Count	Percentage	Count	Percentage
< 0.5 km	631	26%	793	33%
0.5–2 km	901	37%	874	36%
2–5 km	596	25%	512	21%
> 5 km	302	12%	252	10%
TOTAL	**2,430**	**100%**	**2,431**	**100%**

8.2.5. Relationship between Mode of Transport and Distance

Access mode v/s distance relationship shows that, respondents staying within 2 Km from metro station prefer walking (45% of total respondents). Respondents residing beyond 2km prefer bus (15%) or two wheeler (10%) for their first mile connectivity.

Table 5: Access mode – distance relationship

Mode of Travel	Mode Wise Access Trips w.r.t Distance (km)				Access Trips Mode Share
	< 0.5 km	0.5–2 km	2–5 km	> 5 km	
Walk	25%	20%	2%	0%	47%
Two Wheeler	0%	7%	6%	4%	17%
Auto	0%	6%	5%	1%	12%
Cab	0%	0%	1%	1%	3%
Bus	0%	3%	9%	6%	18%
Car	0%	1%	1%	1%	3%
Share Taxi	0%	0%	0%	0%	0%
TOTAL					100%

Similarly, for egress trips for the distance of 2km from the Metro station walking is the most preferred mode (55%). For the distance greater than 2 km respondents prefer either bus (13%) or auto (8%) for their last mile commute.

Table 6: Egress mode – distance relationship

Mode of Travel	Mode Wise Egress Trips w.r.t Distance (km)				Egress Trips Mode Share
	< 0.5 km	0.5–2 km	2–5 km	> 5 km	
Walk	32%	23%	2%	0%	57%
Two Wheeler	0%	4%	3%	1%	8%
Auto	0%	6%	7%	1%	14%
Cab	0%	1%	2%	2%	4%
Bus	0%	2%	7%	6%	15%
Car	0%	0%	0%	0%	1%
Share Taxi	0%	0%	0%	0%	1%
TOTAL					100%

8.2.6. Relationship between Mode of Transport and Travel Time

Table 77 shows the relation between access mode share and the time taken for the respective journeys. Out of the 47% of the access trips by walking, it is observed that 36% of the respondents take less than 10 minutes to reach the Metro station whereas 10% of the respondents take 10-20 minutes. Cab users take 10-20 minutes to reach the Metro station, whereas the majority of the two wheeler users reach the Metro station in 0-20 minutes.

Table 7: Access time–mode relationship

Mode	Mode Wise Access Trips w.r.t Time (minutes)							Access Trips Mode Share
	0-10	**10-20**	**20-30**	**30-40**	**40-50**	**50-60**	**>60**	
Walk	**36%**	**11%**	0%	0%	0%	0%	0%	47%
Two Wheeler	8%	7%	2%	0%	0%	0%	0%	17%
Auto	4%	6%	1%	1%	0%	0%	0%	12%
Cab	1%	1%	1%	0%	0%	0%	0%	3%
Bus	3%	8%	4%	1%	1%	1%	0%	18%
Car	1%	1%	1%	0%	0%	0%	0%	3%
Share Taxi	0%	0%	0%	0%	0%	0%	0%	0%
Total Access trips								100%

Table 88 shows the relation between egress mode share and time taken for the respective journeys. Out of the 57% egress trips by walking, 44% of the respondents take less than 10 minutes to reach their destination from the alighting Metro station whereas 13% take 10-20 minutes. Most of the two wheeler and auto users take less than 20 minutes to reach their destination.

Table 8: Egress time–mode relationship

Mode	Mode wise egress trips w.r.t Time (minutes)							Egress Trips Mode Share
	0-10	**10-20**	**20-30**	**30-40**	**40-50**	**50-60**	**>60**	
Walking	**44%**	**13%**	0%	0%	0%	0%	0%	57%
Two Wheeler	4%	3%	1%	0%	0%	0%	0%	8%
Auto	5%	8%	2%	0%	0%	0%	0%	14%
Cab	1%	2%	1%	0%	0%	0%	0%	4%
Bus	2%	5%	4%	1%	1%	1%	0%	15%
Car	0%	0%	0%	0%	0%	0%	0%	1%
Share Taxi	0%	0%	0%	0%	0%	0%	0%	1%

Total Egress trips	100%

It shows that 85% respondents spend less than 20 minutes for their access trips. Similarly, 88% spend less than 20 minutes for their egress trips. Only the respondents using bus as first or last mile connectivity spend more than 30 minutes for their access or egress trip.

In summary, the access and egress trips within a radius of 0.5 km are not considered for mode choice analysis and identification of feeder routes. This is because Metro users within a walkable range are not potential users for feeder services. For feeder route analysis, 74% of the access trips and 67% of the egress trips are considered.

9. Findings and Discussion

Results of the detailed analysis are described in the following section.

9.1. Expected Shift to Metro Feeder Service

In this study to estimate the probability of shift from the current access and egress modes of transport to Metro feeder service, the Discrete Choice Model (DCM) was used. The socio-economic data, travel characteristics data and the willingness to shift to Metro feeder service from current modes of transport (captured during the Metro passenger opinion survey) served as an input for DCM. A detailed explanation of the DCM is given in Annexure 7.

To understand this shift, a Multinomial Logit Discrete Choice Model (Koppelman and Bhat 2006) was developed using BIOGEME[2] considering the revealed preference (RP) and stated preference (SP) survey data (collected from the Metro passenger opinion survey). The current mode of transport was considered from the RP data and the preferred mode of transport was considered from the SP data. The probability of shift was calculated for different scenarios.

The Metro passenger opinion survey was designed to collect current mode (two wheeler, cars, auto, cab, shared taxi, bus) travel time and travel cost data. Therefore, the scenarios to understand the willingness to shift to a new mode (Metro feeder) was defined in terms of these two parameters for AC and non-AC services. Details of the scenarios are given in Table 99.

Table 9: Scenario details

Scenarios	Travel Cost	Frequency	Comfort
Scenario 1	Equivalent to existing AC bus fare	15 minutes	AC Service
Scenario 2	20% reduction in existing AC bus fare	10 minutes	
Scenario 3	Equivalent to existing ordinary bus fare	15 minutes	Non-AC Service
Scenario 4	20% reduction in existing ordinary bus fare	10 minutes	

The expected shift to Metro feeder service, at select 12 Metro stations, from the current mode of access is shown in Table 10. For access trips, Goraguntepalya, SV Road, Mysore Road and Indiranagar appear favourable for feeder bus services. A maximum willingness of 44% is estimated at SV Road Metro station for Scenario 2. The probability of shift calculations for SV Road Metro station are detailed in Annexure 7.

[2] Biogeme is an open-source software product designed for the maximum likelihood estimation of parametric models in general, with a special emphasis on discrete choice models.

Table 10: Probability of shifting to Metro feeder service - Access

Survey Location	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Attiguppe	37%	40%	31%	35%
Baiyappanahalli	39%	42%	32%	36%
Banashankari	38%	41%	32%	36%
Goraguntepalya	39%	43%	34%	38%
Indiranagar	39%	42%	33%	38%
Kuvempu Road	34%	38%	30%	34%
MG Road	37%	40%	32%	36%
Majestic	35%	38%	29%	34%
Mysore Road	39%	42%	32%	37%
Nagasandra	37%	40%	31%	36%
SV Road	42%	44%	34%	38%
Vidhana Soudha	37%	41%	32%	36%

Table 1111 shows the scenario-wise and station-wise willingness of respondents to shift to Metro feeder service for their egress trips. The maximum willingness to shift is estimated at Indiranagar and SV Road Metro station. For these two Metro stations, Scenarios 2 and 4 get a comparatively high figure.

Table 11: Probability of shifting to Metro feeder service - Egress

Survey Location	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Attiguppe	32%	38%	33%	38%
Baiyappanahalli	30%	35%	31%	36%
Banashankari	32%	37%	32%	38%
Gorguntepalya	32%	38%	33%	38%
Indiranagar	33%	39%	34%	39%
Kuvempu Road	27%	33%	28%	33%
MG Road	30%	35%	31%	36%
Majestic	29%	35%	30%	35%
Mysore Road	31%	36%	31%	37%
Nagasandra	31%	37%	31%	37%
SV Road	34%	40%	35%	40%
Vidhana Soudha	31%	38%	32%	38%

For the stations identified where there is a maximum potential to shift to feeder services, the study proposes preliminary feeder services. The preliminary feeders were proposed based on a combination of maximum desire lines, activity centres, road inventory and existing feeder routes.

9.2. Potential Metro Stations for Feasible Metro Feeders

Based on the DCM results and desire line diagram, Metro stations which have a potential for BMTC feeders service have been identified. The list of identified Metro stations is given below:

- SV Road
- Baiyappanahalli
- Mysore Road
- Goraguntepalya
- Banashankari
- Yelachenahalli

As SV Road and Baiyappanahalli are already well connected with BMTC Metro feeder routes, new feeder routes for the remaining stations were proposed. The proposed routes were designed such that the travel time for one trip should not exceed 30 minutes. The station-wise proposed feasible routes are shown in the maps below. The feasibility of the proposed routes needs to be validated by the stakeholder (BMTC).

9.3. Proposed Feeders at Banashankari Metro Station

Table 12: Details of proposed feeder routes at Banashankari Metro station

Origin	Destination	Via Route	MS Covered	Type	Route Length
Banashankari MS	Banashankari MS	Chikkalasandra, Padmanabha Nagar, Banashankari 2nd stage	Banashankari, JP Nagar, RV Road	Circular	11.2 km

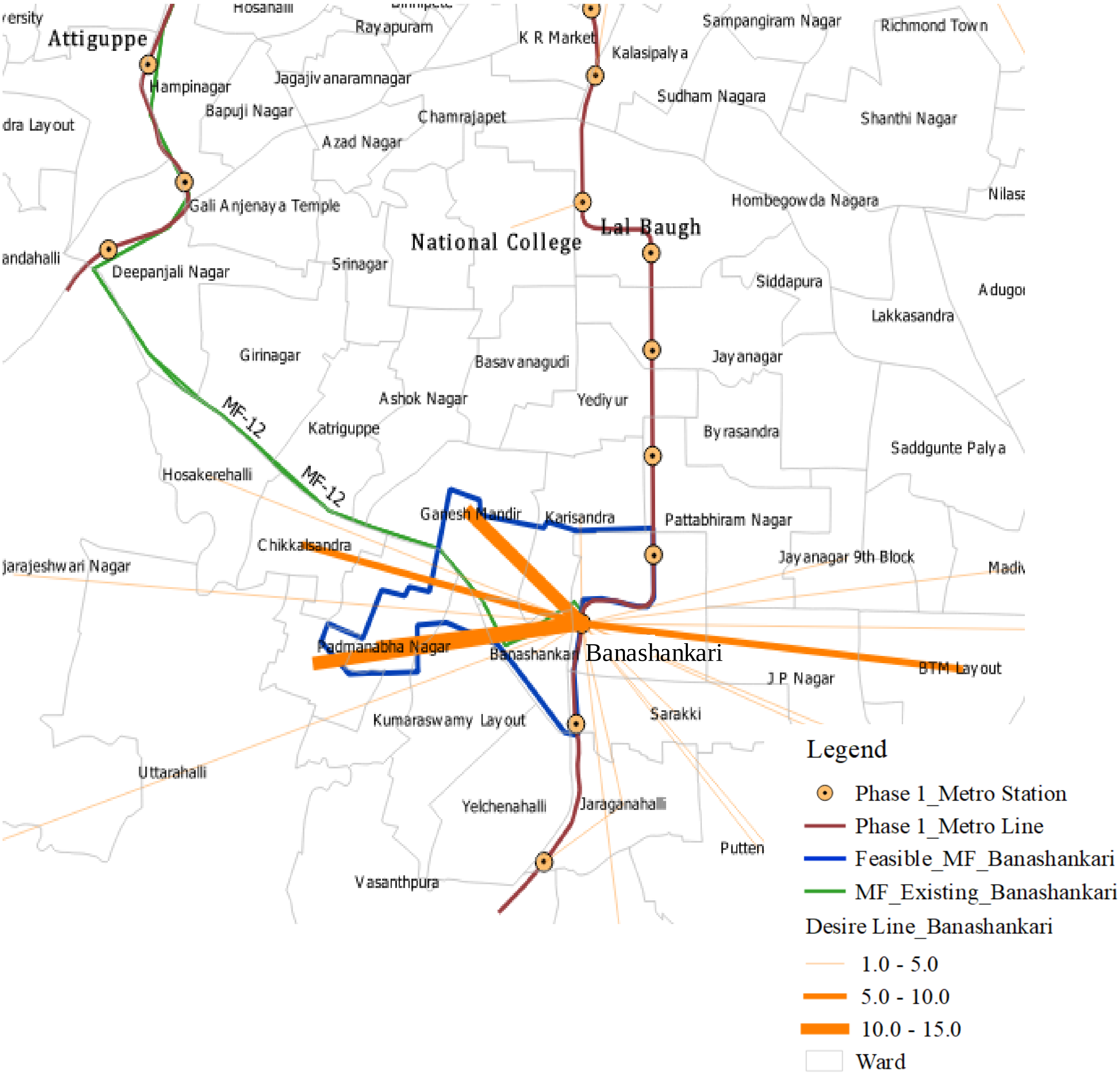

Figure 8: Proposed feeder routes at Banashankari Metro station

9.4. Proposed Feeders at Goraguntepalya Metro Station

Table 13: Details of proposed feeder route at Goraguntepalya Metro station

Origin	Destination	Via Route	MS Covered	Type	Route Length
Goraguntepalya	JP Park Chodeshwari BS	Mathikere Circle, Yeshwantpur RTO, Yeshwantpur TTMC	Sandal Soap Factory, Yeshwantpur, Goraguntepalya	Trunk	5.2 km

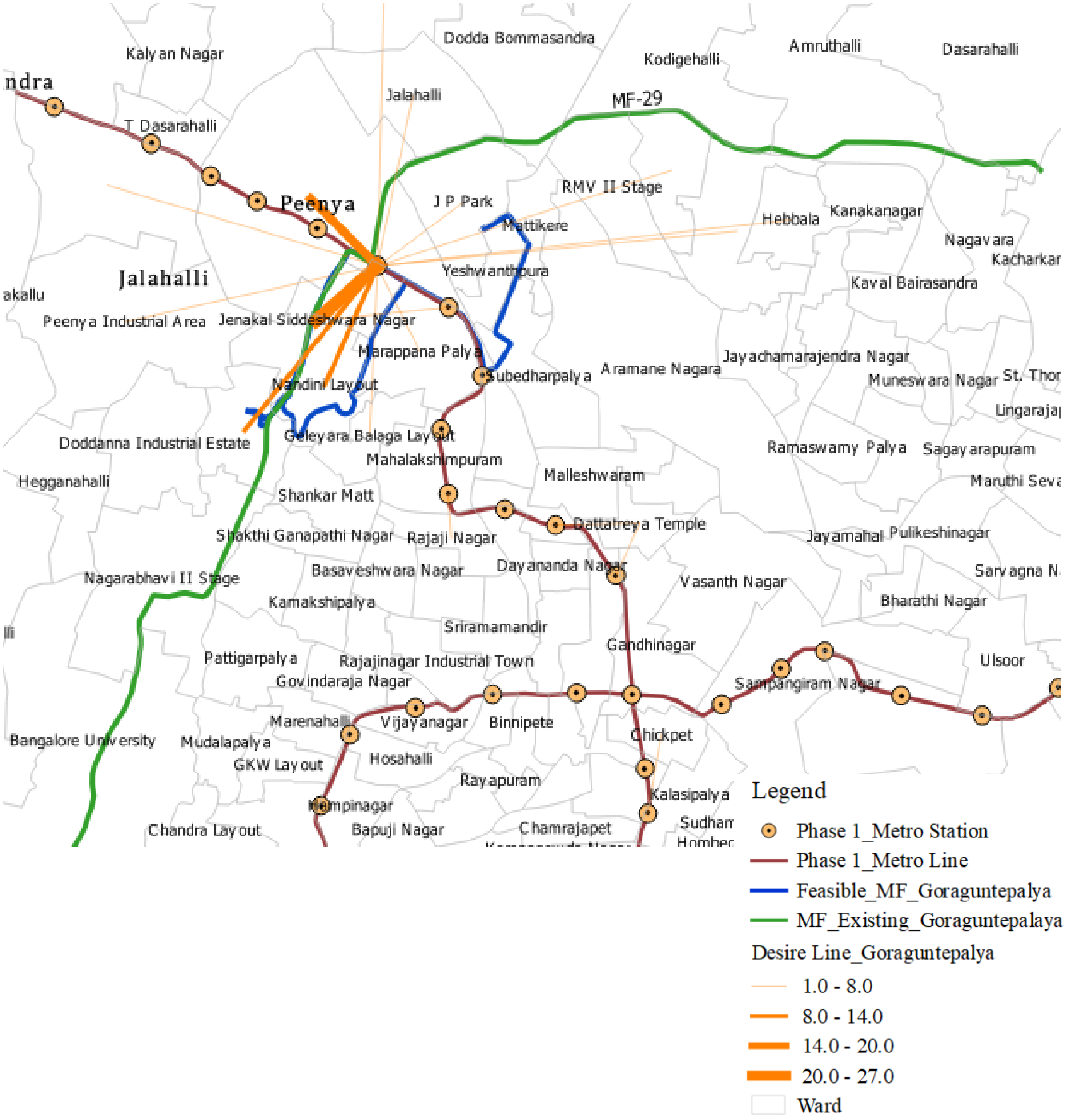

Figure 9: Proposed feeder routes at Goraguntepalya Metro station

9.5. Proposed Feeders at Mysore Road Metro Station

For Mysore Road Metro station, two feeder routes (MF -12, MF-14) are currently operated by BMTC. The access trips towards Rajarajeshwari nagar is already served by MF -14 and the other access trips towards Hemmigepura is well connected with the existing bus routes. So for this metro station, new Metro feeder was proposed connecting adjacent metro station (Deepanjali nagar), satellite bus station, and adjacent residential & commercial areas.

Table 14: Details of proposed feeder routes at Mysore Road Metro station

Origin	Destination	Via Route	MS Covered	Type	Route Length
Mysore Satellite BS	Mysore Satellite BS	Girinagar, Srinagar	Mysore Road, Deepanjali Nagar	Circular	10 km

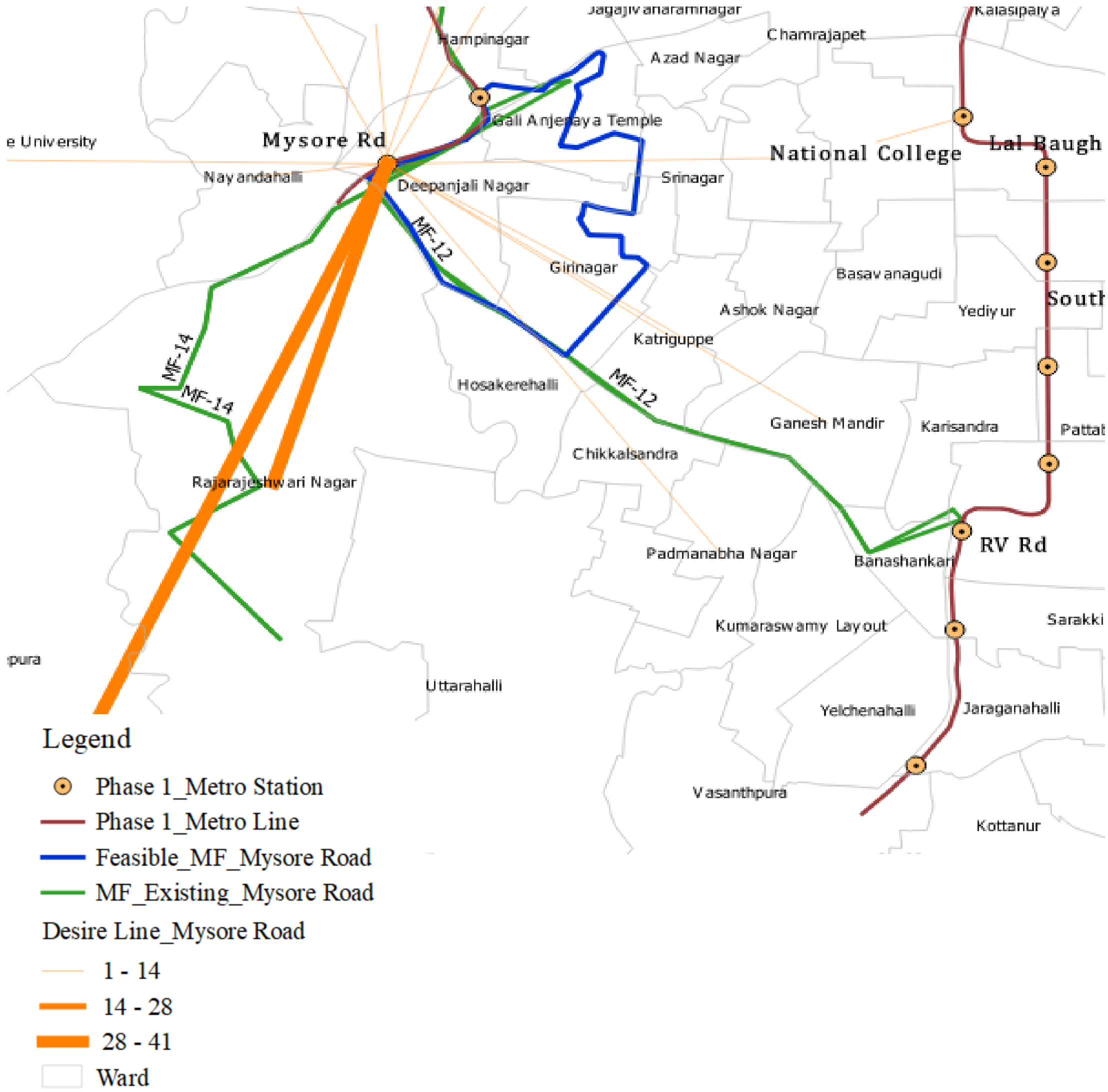

Figure 10: Proposed feeder routes at Mysore Road Metro station

9.6. Proposed Feeders at Yelachenahalli Metro Station

The proposed Metro feeder is based on connecting potential activity centres, adjacent Metro station (J P Nagar) and the areas for which this Metro station is closest. This proposed feeder also connects underserved BMTC routes (e.g. Gottigere to Yelachenahalli Metro station). The trips towards Kanakpura Road were not considered for proposing new Metro feeder service, as this location is well connected with existing BMTC bus services.

Table 15: Details of proposed feeder routes at Yelachenahalli Metro station

Origin	Destination	Via Route	MS Covered	Type	Route Length
Yelachenahalli MS	Yelachenahalli MS	Gottigere, Kottanur, Sarakki	Yelachenahalli, JP Nagar	Circular	12.9 km

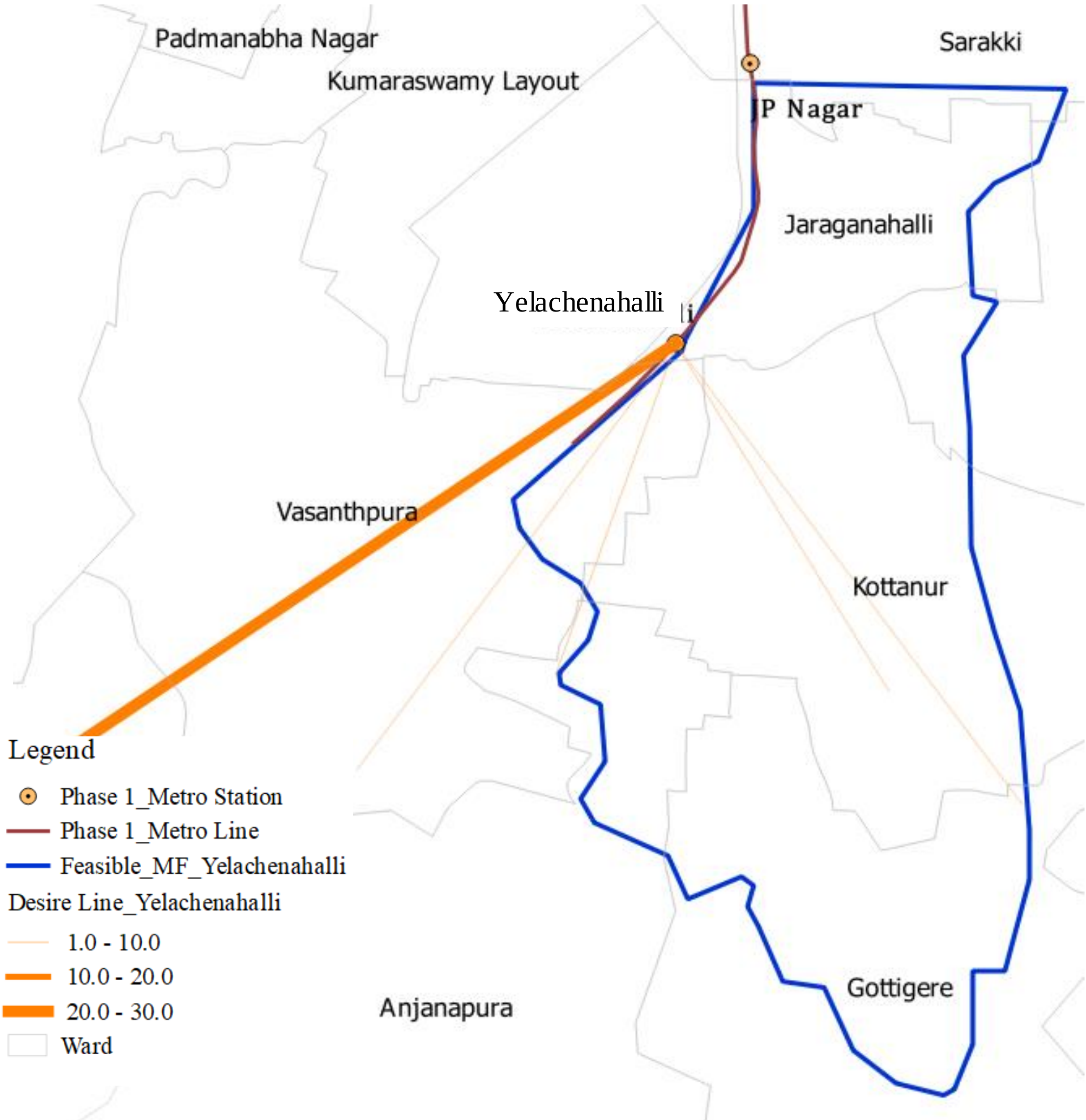

Figure 11: Proposed feeder routes at Yelachenahalli Metro station

10. Conclusions and Recommendations

Through this study, socio-economic and trip characteristics of current Metro users were collected through an opinion survey. The survey captured the users' willingness to shift to feeder service for both access and egress trips, under four scenarios (with varying frequency and travel cost). DCM was used to analyse the probability of shift from their current mode of transport to feeder service. The Metro stations where there is a maximum probability of shift are considered for proposing new feeder routes. Access and egress trip travel patterns, existing feeder services and activity centres were considered to propose new feeder routes.

The proposed feeder routes can serve as a basis for running trial services. This study methodology can be considered for future Metro feeder design.

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Annexure I

Feeder Routes – February 2018

Route No.	Origin	Destination	Route Length (km)	Schedules	Metro Station
MF-1	SV Road MS	Whitefield TTMC	8.5	56	SV Road, Baiyappanahalli
MF-1A	SV Road MS	SV Road MS	23	14	SV Road, Baiyappanahalli
MF-2	HAL Main Gate	TC Palya	23	19	SV Road, Baiyappanahalli
MF-2A	SV Road MS	HAL Main Gate	5	16	SV Road, Baiyappanahalli
MF-3	Baiyappanahalli MS Back Gate	K R Puram	7.1	27	Baiyappanahalli
MF-5	Central Silk Board	Old Baiyappanahalli	9.8	18	SV Road
MF-6	Central Silk Board	SV Road MS	9.9	83	SV Road
MF-8	Kalyananagara Bus Stand	Baiyappanahalli MS Back Gate	7.8	28	Baiyappanahalli
MF-12	Banashankari TTMC	Vijayanagar	10.1	59	Vijayanagar, Attiguppe, Deepanjalinagar, Mysore Road, Banashankari
MF-13	Vijayanagar	Vijayanagar	20.4	11	Attiguppe, Vijayanagar
MF-14	BEML Layout 5th Stage	Mysore Road Satellite Bus Stand	8.5	7	Mysore Road, Deepanjalinagar
MF-23	Jalahalli MS	Vidyaranyapura	8.5	63	Jalahalli
MF-24	Nagasandra MS	Chikkabanawara	4.3	69	Nagasandra
MF-26	Kanakagiri Horamvu	Baiyappanahalli MS Back Gate	7.6	15	SV Road, Baiyappanahalli
MF-27	Nagasandra MS	Nagasandra MS	13.5	82	Nagasandra
MF-28	Peenya 2nd stage	Peenya 2nd stage	9.7	29	Peenya
MF-29	Nagavara	Kengeri TTMC	28.9	28	Goraguntepalya
V-MF-1	SV Road MS	SV Road MS	24	29	SV Road, Baiyappanahalli

Route No.	Origin	Destination	Route Length (km)	Schedules	Metro Station
VMF-1A	SV Road MS	SV Road MS	28	27	SV Road, Baiyappanahalli
VMF-1B	SV Road MS	Whitefield TTMC	11	64	SV Road, Baiyappanahalli
VMF-10	Central Silk Board	K R Puram	13	14	SV Road, Baiyappanahalli
VMF-11	SV Road MS	ITPL	11	15	SV Road, Baiyappanahalli
VMF-15	Baiyappanahalli MS Back Gate	Hebbal	12	20	SV Road, Baiyappanahalli

Annexure II

Stratified Random Sampling

Stratified Random Sampling is a method of sampling where the population is divided into homogenous groups ($N_1, N_2, N_3 \ldots$) known as strata. Simple Random Sampling (SRS) method is then used in each stratum to drawn samples. The advantage of this method is that it narrows the difference between different types of individuals through classification, which extracts representative samples and reduces the sample size (Shi 2014).

Steps in stratified random sampling:

The first step involved in the stratified random sampling method was to divide the population into different strata. Since the study area was the Phase I Metro corridor, the entire area was divided into different strata based on the Metro station typology. Six different strata were formed and the total population for these strata ($N_1, N_2, N_3 \ldots$) was the sum of the boarding passengers.

The sample size was calculated for each stratum using the SRS formula:

$$n_1 = \frac{Z^2 \times p(1-p)}{e^2}$$

$$n'_1 = \frac{n_1 \times N_1}{n_1 + N_1}$$

$$n = n_1 + n_2 + n_3 + \text{------} + n_h$$

Where,

n_1 = Sample size for each stratum

n'_1 = Finite population correction for stratum

N_1 = Population for stratum

n = Total sample size

Z = Z – Score (Z-Table value for 95% confidence interval is 1.96)

e = Margin of Error (5%)

p = Prior judgment of the correct value (probability), which is 0.5 here

Annexure III

Sample Size Distribution

Period of Survey – Jan 24 to Feb 9, 2018

Sl No	Metro Station	Date	Time Period			Total Sample Size	Direction			
			T1	T2	T3		N	S	E	W
1	Majestic	24.01.2018 25.01.2018	80	34	59	**173**	58	44	40	31
2	Baiyappanahalli	29.01.2018 08.02.2018	42	137	30	**209**	0	0	0	209
3	Nagasandra	29.01.2018 08.02.2018	36	91	33	**160**	0	160	0	0
4	Banashankari	29.01.2018 07.02.2018	63	99	60	**222**	222	0	0	0
5	Mysore Road	30.01.2018	94	41	37	**172**	0	0	172	0
6	MG Road	31.01.2018 06.02.2018	60	100	50	**210**	0	0	105	105
7	Indiranagar	30.01.2018 06.02.2018	77	131	43	**251**	0	0	126	125
8	Vidhana Soudha	31.01.2018 06.02.2018	35	88	30	**153**	0	0	76	77
9	SV Road	31.01.2018	79	86	35	**200**	0	0	0	200
10	Attiguppe	01.02.2018 08.02.2018	86	55	40	**181**	0	0	91	90
11	Kuvempu Road	01.02.2018 08.02.2018	53	80	38	**171**	85	86	0	0
12	Goraguntepalya	01.02.2018 07.02.2018	88	82	40	**210**	105	105	0	0
	TOTAL					**2,312**				

Annexure IV

Secondary Data Collection Template

Feeder Route No.	Origin	Destination	Route Length

Annexure V

Metro Passenger Opinion Survey Questionnaire

(At Metro Stations)

Purpose: To identify feasible Metro feeder routes and also to assess the impact of Metro on BMTC services

Survey location: Date & Time:

Gender	Male	Female

Age group	Less than 18	19–30	31–50	51–60	Above 60

1. Employment type:
   a) Working
   b) Unemployed
   c) Retired
   d) Student
   e) Homemaker
   f) Others

2. Monthly household income	Less than INR 10,000	INR 10,000–20,000	INR 20,000–50,000	INR 50,000 –1,00,000	More than INR 1,00,000

3.

Origin (Landmark, Nearest Bus Stop & PIN Code)	Destination (Landmark, Nearest Bus Stop & PIN Code)
Boarding Metro Station	Alighting Metro Station

4. Purpose of travel	Education	Work	Leisure	Social	Other

5. How often do you make this trip?	Daily	Weekly	Monthly

6. How long have you been using Metro?

Less than 3 months	3 to 6 months	6 to 9 months	More than 9 months

7. What was your previous mode of travel?

Cycle	Two Wheeler	Auto	Bus Route No. ________	Private Car	Taxi/ Cab	Commuter Rail

8. If the answer is BMTC, what prompted you to shift to Metro?

Sl No.	Reasons	Response
1	Travel time	
2	Comfort	
3	Low bus frequency / High waiting time for BMTC	
4	Reasonable Metro fare	
5	Avoid traffic jams and pollution	

9. How did you reach the Metro station?

Walk	Car	Two Wheeler	Auto	Bus Route No. ________	Cab/ Taxi	Share Taxi

10. Home to Metro station distance

Less than 0.5 km	0.5–2 km	2–5 km	More than 5 km

11. Travel Time to reach Metro station: ________________ minutes

12. Do you use the same mode for returning to your origin? Yes/No

13. How will you reach your destination from the Metro station?

Walk	Car	Two Wheeler	Auto	Bus Route No. ________	Cab/ Taxi	Share Taxi

14. Metro station to final destination distance

Less than 0.5 km	0.5–2 km	2–5 km	More than 5 km

15. Travel time to reach your destination from the Metro station: ______________ minutes

16. Do you use the same mode to reach Metro station from destination? Yes/No

17. Do you park your vehicle at the Metro station? Yes/No

18. Do you pay for parking? Yes/No

19. Scenarios and ranking (Would you shift to Metro feeder if ...)

Scenario	Current Mode Travel Cost	Current Mode Travel Time	Metro Feeder Travel Cost	Metro Feeder Travel Time (Min)	Comfort	Your Response	
						Current Mode	Metro Feeder
1				IVTT*+30	AC		
2				IVTT+24	AC		
3				IVTT+30	AC		
4				IVTT+24	AC		
5				IVTT+30	Non-AC		
6				IVTT+24	Non-AC		

*IVTT – In Vehicle Travel Time

20. Any other suggestions for improvement?

Annexure VI

Socio-Economic Profile of Respondents

Profile of Respondents	Category Range	Respondents	
		Count	Percentage
Gender	Male	1,314	54%
	Female	1,118	46%
TOTAL		**2,432**	**100%**
Age	<18	53	2%
	19–30	1,205	50%
	31–50	1,013	42%
	51–60	119	5%
	Above 60	44	2%
TOTAL		**2,434**	**100%**
Employment Type	Working	1,698	70%
	Unemployed	116	5%
	Retired	58	2%
	Student	326	13%
	Homemaker	189	8%
	Others	42	2%
TOTAL		**2,429**	**100%**
Monthly Household Income	< INR 10, 000	207	9%
	INR 10,000–20,000	420	18%
	INR 20,000–50,000	1,271	53%
	INR 50,000–1,00,000	427	18%
	> INR 1,00,000	70	3%
TOTAL		**2,395**	**100%**

Annexure VII

Discrete Choice Model

The study developed a Multinomial Logit Discrete Choice Model to understand Metro users' willingness to shift to Metro feeder service from the current mode of transport, based on their stated preference (SP) and revealed preference (RP) (Metro Passenger Opinion Survey). The socio-economic data, travel characteristics data and the willingness to shift from the current mode (captured in the survey) serve as inputs to the model.

The general expression for the probability of choosing an alternative 'i' (i = 1, 2, … j) from a set of j alternatives is:

$$P_r(i) = \frac{exp\ (V_i)}{\sum_{j=1}^{J} exp\ (V_j)}$$

Where

P_r (i) is the probability of the decision-maker choosing the alternative i, and

V_j is the deterministic utility function of the alternative j, which is generally represented by:

$$\mathrm{V}(X_i) \quad = \gamma_1 \times X_{i1} + \ \gamma_2 \times X_{i2} + \cdots \ldots \ldots . . \gamma_k \times X_{ik} + ASC$$

Where

γ_k is the parameter which defines the direction and importance of the effect of the attribute k on the utility of an alternative,

X_{ik} is the value of the attribute k for the alternative i, and

ASC is the Alternative Specific Constant (Error term which is unobserved and unmeasured).

The respondents were given four scenarios and asked to choose between the given mode (Metro feeder) and their current access/egress mode. The scenarios differ in travel cost, travel time and comfort (AC and non-AC service). The scenarios considered for the study are shown in Table 9.

Travel time for the proposed Metro feeder bus was considered based on in-vehicle time and out-vehicle time. The in-vehicle time was estimated by dividing the respondents' distance between origin and destination by the average journey speed in Bengaluru, that is, 15 kmph (Urban Mass Transit Company Limited 2011). The out-vehicle time was estimated considering walking time of five minutes (Diyanah, Hafazah, and Mohd Zamreen 2012) to reach the bus stop and waiting time at the bus stop based on the frequency of bus.

Travel time and travel cost for all the other current access/egress modes were calculated. Travel time was estimated by dividing the distance between the origin and the destination of the respondents by the average journey speed in Bengaluru. Travel cost for two wheeler and car was based on the petrol price and mileage of the respective modes. For auto, fare was calculated by taking a minimum charge of INR 25 for the first 2 km and INR 13 for each additional km (travel2karnataka 2017). For bus, fare was considered from the BMTC stage-wise fare data (BMTC 2018a).

Model Structure

Utility of a mode is defined in terms of mode attributes such as travel time and travel cost as well as socio-economic characteristics (Raturi and Verma 2017). The Multinomial Logit Model was developed by considering Metro users' access and egress modes and Metro feeder service (bus). Separate models for first mile (access) and last mile (egress) were developed. Ordinary bus users were also considered in the model, to understand their willingness to shift to Metro feeder services under different scenarios. Shared taxi users for the first mile model and cars and shared taxi users for the last mile model were excluded as the number of respondents under those categories was very less.

Utility function for each alternative in RP & SP is given in Equations 1 and 2 respectively. Utility equations corresponding to SP are multiplied with a parameter λ, an unknown parameter to reflect the impact of unobserved factors that are necessarily different in real-choice situations than in hypothetical survey situations (Train 2002). The explanatory variables considered are Alternative Specific Constant (ASC), travel cost (Cost), travel time (Time) and household income (Income). Two wheeler was considered as the base or reference alternative, so the ASC of two wheeler was fixed to zero.

$$U_j^{RP} = ASC_j^{RP} + \beta_1 \times Time_j + \beta_2 \times Cost_j + \beta_{3j} \times Household\ Income \quad (1)$$

$$U_j^{SP} = (ASC_j^{SP} + \beta_1 \times Time_j + \beta_2 \times Cost_j + \beta_{3j} \times Househole\ Income)\lambda \quad (2)$$

Estimated Parameters

The model considered data from 6,899 observations for the first mile and 4,787 observations for the last mile. The contribution of each attribute to the utility of an alternative is indicated by the sign of its coefficients. A positive value indicates a direct correlation on the utility and the negative value indicates an inverse correlation (Bajracharya 2008). The negative sign of travel time and travel cost indicates that higher the travel time and cost, lower is the probability of choosing that alternative.

First Mile Model

The coefficients estimated from this model for the probability of shift to Metro feeder for the first mile are presented in Table 16. A negative sign of travel time indicates that higher the travel time, lower is the probability of choosing Metro feeder service. Also, a negative sign of income indicates that higher the monthly household income, lower is the probability of choosing Metro feeder service.

Table 16: Estimated coefficients –First mile model

Attribute	Value	p-value
ASC_AUTO_SP	0.569	0
ASC_BUS_SP	3.22	0
ASC_CAB_SP	-1.57	0
ASC_CAR_SP	0	
ASC_MF_SP	3.99	0
ASC_TW_SP	2.16	0
ASC_WALK_SP	4.31	0
B_COST	3.23	0
B_INCOME_BUS	-0.178	0
B_INCOME_MF	-0.00871	0.51
B_INCOME_WALK	-0.146	0
B_TIME	-5.23	0
LAMBDA	0.973	0

Last Mile Model

The coefficients estimated for the probability of shift to Metro feeder for the last mile are presented in Table 17. A negative sign of travel cost and travel time indicates that higher the travel cost and travel time, lower is the probability of choosing Metro feeder service. Also, a negative sign of income indicates that higher the monthly household income, lower is the probability of choosing Metro feeder service.

Table 17: Estimated coefficients–Last mile model

Attribute	Value	p-value
ASC_AUTO_SP	0.676	0
ASC_BUS_SP	0.928	0
ASC_CAB_SP	-0.486	0
ASC_MF_SP	1.59	0
ASC_TW_SP	0	
ASC_WALK_SP	2.11	0
B_COST	-0.406	0.05
B_INCOME_BUS	-0.0559	0
B_INCOME_MF	0.0586	0
B_INCOME_WALK	-0.0349	0.02
B_TIME	-4.85	0
LAMBDA	1.2	0