Initiative 2: Feasibility of New Routes for High-End AC Buses

Initiative 2: Feasibility of New Routes for High-End AC Buses

Abbreviations and Acronyms

AC	Air Conditioned
ASC	Alternative Specific Constant
BBMP	Bruhat Bengaluru Mahanagara Palike
BEL	Bharat Electronics Limited
BMRCL	Bangalore Metro Rail Corporation Limited
BMTC	Bengaluru Metropolitan Transport Corporation
DCM	Discrete Choice Modelling
HH	Household
INR	Indian Rupee
IPT	Intermediate Public Transport
IT	Information Technology
ITPL	International Tech Park Limited
IVTT	In Vehicle Travel Time
KBS	Kempegowda Bus Station
Km	Kilometre/s
K. R. Puram	Krishna Raja Puram
MNL	Multinomial Logit Model
NES	National Employment Service
O. Bus	Ordinary Bus
ODK	Open Data Kit
ORR	Outer Ring Road
P. Bus	Private Bus
RP	Revealed Preference
SP	Stated Preference
S. V. Road	Swami Vivekananda Road
TT	Tempo Traveller
TW	Two-wheeler

Executive Summary

Bengaluru Metropolitan Transport Corporation (BMTC) operates AC bus services (Vajra services) mainly along the IT corridors, Outer Ring Road (ORR) and other major transport corridors in the city. These services were earning profits till 2013-14, 2014-15 and 2015-16. However, 2016 onwards, they started incurring losses because of increased operational costs. Moreover, in the last few years, BMTC has witnessed a decrease in AC bus ridership as commuters are shifting to Metro and app-based cab aggregators. Due to decreasing AC bus ridership and increasing operational costs, it was challenging for BMTC to operate these services.

In an effort to retain its ridership, BMTC introduced initiatives such as flexible tariff during non-peak hours and reduction in fare. The reduction in fare (introduced in January 2018) has yielded a 44% increase in AC bus ridership, compared with the previous year. To further increase the ridership of AC bus services, BMTC intends to determine the potential demand for such services. In this context, this study aims to explore the feasibility of introducing new, high-end AC buses in Bengaluru for better service to commuters. The study also aims to identify the feasible directions of operation of AC bus services for the locations surveyed.

For this study, a commuter survey was conducted at eight select locations. From the survey data, passengers' travel characteristics and patterns were analysed. The study estimates the willingness to shift to AC bus services from existing modes of transport (two-wheelers, cars, ordinary[1] buses, private buses, autos and cabs). The study concludes with the identification of potential corridors for introduction of AC bus services. The results indicate that approximately 25% of the respondents were willing to shift to AC bus services, irrespective of the variation in fare and time. It was observed that the maximum potential shift was from autos and two-wheelers to AC bus services, and there was minimal shift from ordinary bus services and private bus services.

[1] Ordinary bus refers to non-AC bus.

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1. Introduction

BMTC started AC bus services (Vajra) on select corridors of the city in 2006 (Financial Express 2006), with a view to provide a premium bus service to commuters. Vajra services mainly operate in the IT corridors and a few residential areas of Bengaluru. Currently, BMTC operates around 89 routes under the Vajra services, with 845 AC buses (Philips 2017).These services were profitable till 2015-16, and were compensating the losses from ordinary services (P K 2012). However, from 2013 onwards, this service has incurred losses due to high operational costs per km. Moreover, in the past few years, BMTC has witnessed a decrease in AC bus ridership as commuters are shifting to Metro and app-based cab aggregators. Due to the decrease in AC bus ridership and increase in operational cost, it was challenging for BMTC to operate these services.

In an effort to retain its ridership, BMTC reduced the fare for AC bus services in January 2018. This reduction in fare has seen an increase in ridership by almost 50% till May 2018. To further increase the ridership of AC bus services, BMTC intends to determine the potential demand for such services.

2. Log Frame/Theory of Change/Programme Theory

AC bus services play a vital role in BMTC bus operations especially along the IT corridors. Given their current coverage, BMTC would like to explore the possibility of expanding such services to cater to the potential demand from commuters using other modes. This could provide a premium public transport for people using private vehicles.

The primary survey for this study was carried out at eight important junctions[2] in the city. These junctions are shown in Figure 1.

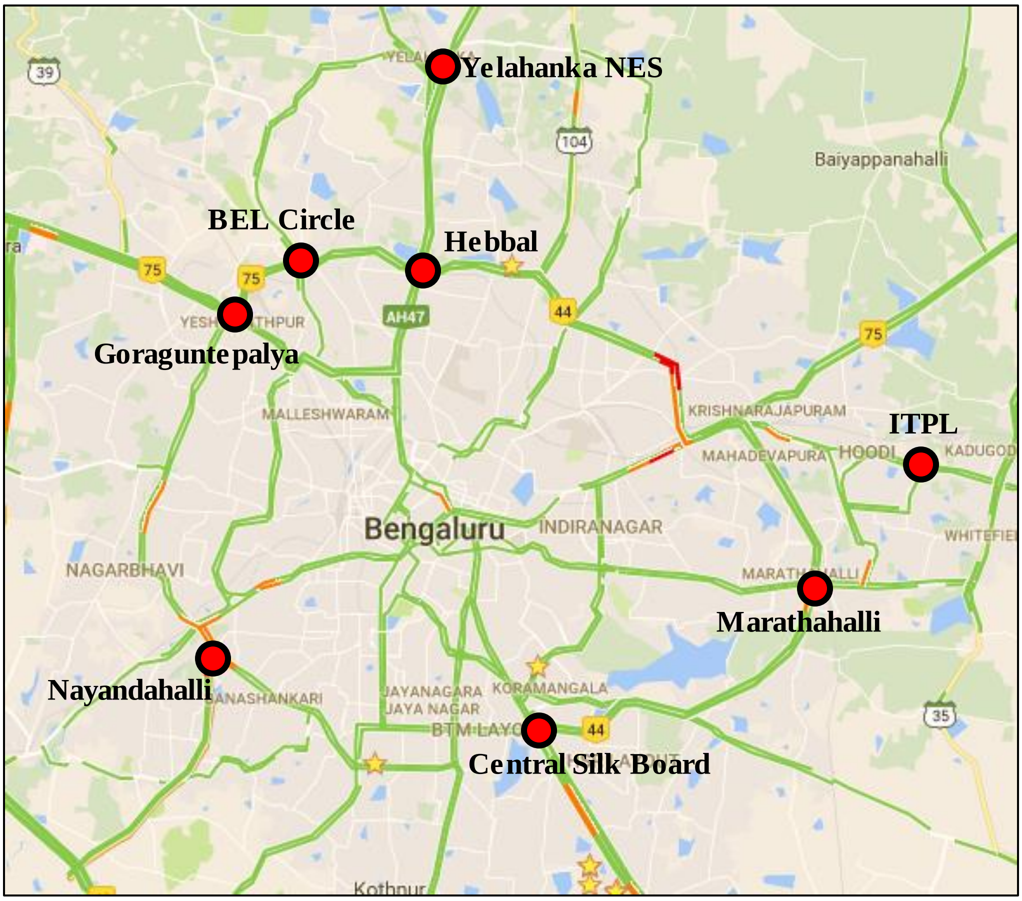

Figure 1: Map showing survey locations

[2] Selection of junctions and directions were finalised in consultation with BMTC.

	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 determine the feasibility of new AC bus services in Bengaluru	*What are the key indicators related to the overall objectives?* • Willingness of commuters to shift from their current mode to the new AC bus services	*What are the sources of information for these indicators?* • Primary survey of non-AC bus users, private vehicle users (two-wheelers and cars), IPT users (auto and cab) and private bus users	
Specific Objectives	*What specific objectives is the activity intended to achieve to contribute to the overall objectives?* • To identify the willingness of commuters to shift to AC services • To identify potential corridors for extension of existing AC bus services and introduction of new AC bus services	*Which indicators clearly show that the objective of the activity has been achieved?* • Probability of commuters shifting from their current mode to new AC bus services • For each survey location, direction-wise predominant trip pattern	*What are the sources of information that exist or can be collected? What are the methods required to get this information?* • Primary survey of non-AC bus users, private vehicle users (two-wheelers and cars), IPT users (auto and cab) and private bus users • Discrete choice modelling (Multi-nominal Logit Model) method to determine the probability of shift from current mode to new AC bus services	*Which factors and conditions outside the PI's responsibility are necessary to achieve that objective?* *Which risks should be taken into consideration?* • Willingness of competent authority to permit the survey • Willingness of competent authority to share the required data • Being able to obtain timely and appropriate responses from the respondents

Expected Results	*The results are the outputs envisaged to achieve the specific objective.* *What are the expected results? (enumerate them)* • Willingness of commuters to shift to new AC bus services • Suggest feasible directions to operate the new AC bus services	*What are the indicators to measure whether and to what extent the activity achieves the expected results?* • Questions addressed by the respondents for different scenarios	*What are the sources of information for these indicators?* • Primary survey of non-AC bus users, private vehicle users (two-wheeler and cars), IPT users (auto and cab) and private bus users • Secondary analysis (probability to shift from current mode to new AC bus service)	*What external conditions must be met to obtain the expected results on schedule?* • Timely availability of survey data from all the survey locations
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. Obtain survey locations from BMTC 2. Conduct primary survey (commuter survey) at these locations 3. Measure commuters' willingness to shift to BMTC's AC bus services 4. Identify potential corridors 5. Validate the suggested corridors with the stakeholder	***Means:*** *What are the means required to implement these activities, e. g. personnel, training, studies, etc.?* • Transport planning experts • Survey experts	*What are the sources of information about action progress?* • Date and time captured during the primary survey • CSTEP supervision during the primary survey • Secondary data from BMTC about existing AC bus services	*What pre-conditions are required before the action starts?* • Permission from competent authorities to conduct the survey • Willingness of competent authority to share the required data

3. Progress Review

BMTC AC services mainly operate along IT corridors, Outer Ring Road (ORR) and to and from the airport. As on March 2018, BMTC runs 845 schedules for approximately 85 AC bus routes. The average route length is about 30 km, with a maximum length of 55 km (Hebbal to Attibele) and a minimum of 13 km (S. V. Road to Whitefield). There are 75 schedules running from Kempegowda Bus Station (KBS) to Kadugodi (which is the highest). Other schedules connect KBS to Attibele, Banashankari to ITPL, and Hebbal to Central Silk Board.

4. Problem Statement

To determine the feasibility of introduction of AC bus services on high traffic density corridors in Bengaluru.

BMTC intends to expand the reach of its AC bus services to improve connectivity and comfort. This study aims to determine the feasibility of introducing AC bus services at eight major junctions covering important corridors in the city.

The study will identify the potential corridors for BMTC to introduce the new AC bus services, based on commuters' willingness to shift from their current mode of transport to such services.

5. Objectives and Issues for Evaluation

Objectives

- To determine the feasibility of introduction of new AC bus services along important corridors
- To identify the feasible direction for operation of AC bus services

Scope

Target population: The target population for this study are all motorised commuters (except BMTC AC bus users) who pass through the select junctions at each survey location.

Geographical coverage: Bengaluru city

6. Evaluation Design

6.1. Information Sources

Primary survey at select junctions in the city and secondary data from BMTC and various relevant literature served as the basis of information for this study.

For primary data collection, a commuter survey was conducted. This survey helped understand the socio-economic characteristics of the respondents and provided information on their travel pattern, origin–destination, commuting cost, time, distance and frequency. It also helped to estimate the willingness of the commuters to shift to new AC bus services with respect to variation in the fare under two different scenarios.

6.2. Evaluation Criteria or Indicators

The feasibility of operating new AC bus services is evaluated on the basis of commuters' willingness to shift from their current mode of transport to new AC bus services.

7. Evaluation Methodology

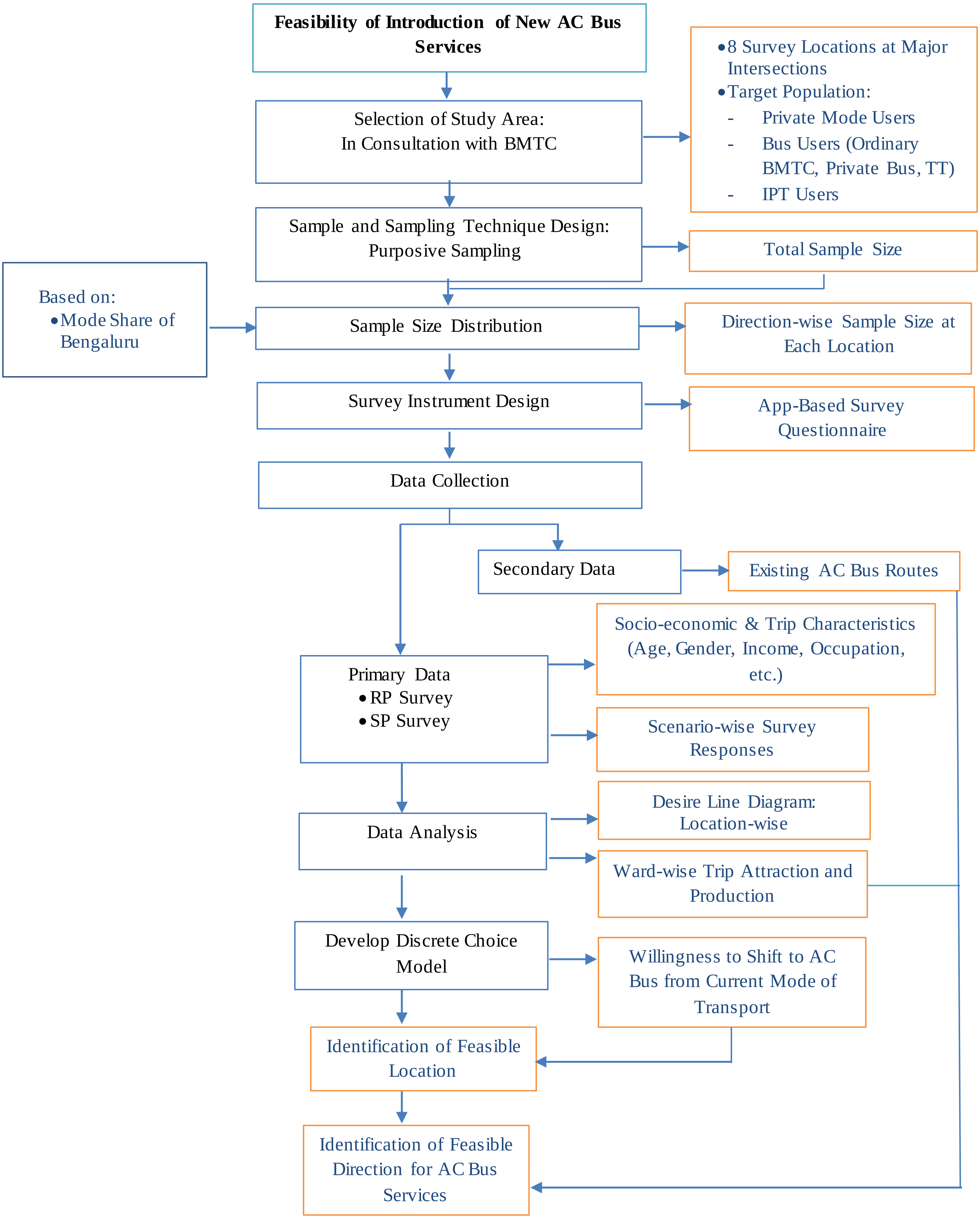

Figure 2: Determining feasibility of introduction of new AC bus services

A systematic and phased approach was adopted for carrying out the study and delivering the results within the stipulated timeframe. The methodology adopted for determining the feasibility of introducing new high-end AC bus routes is explained in the following sections.

7.1. Sample and Sampling Design

The survey locations (Figure 1) are major interchange junctions in the city. The survey sample was distributed at each junction in different directions to capture the required data.

To determine a representative sample size from an infinite population (where the population size is greater than 50,000), the Simple Random Sampling (SRS) formula was used (Sarmah and Hazarika 2012).

$$n_0 = \frac{Z^2 \times p(1-p)}{e^2}$$

Where

n_0 = Sample Size

Z = Z Score Value

e = Margin of Error (5%)

p = Prior Judgment of the Correct Value (probability), which is 0.5 here

Using the equation presented above, the minimum sample size comes out to be approximately 384 for 95% confidence level and approximately 666 for 99% confidence level (calculations are shown in Annexure I). Therefore, a minimum sample size of 600 was considered for this survey. At junctions where a multi-directional survey was planned, the sample size considered for this study was 800 or 1,000.

The sample size thus arrived at (for each location) was distributed across different modes of transport, such as two-wheelers, autos, cabs, cars, private bus and ordinary BMTC bus, based on the mode share of Bengaluru (DULT 2010). The survey locations and directions are given in Figure 3, and the direction and mode-wise sample size at each location are given in Table 1.

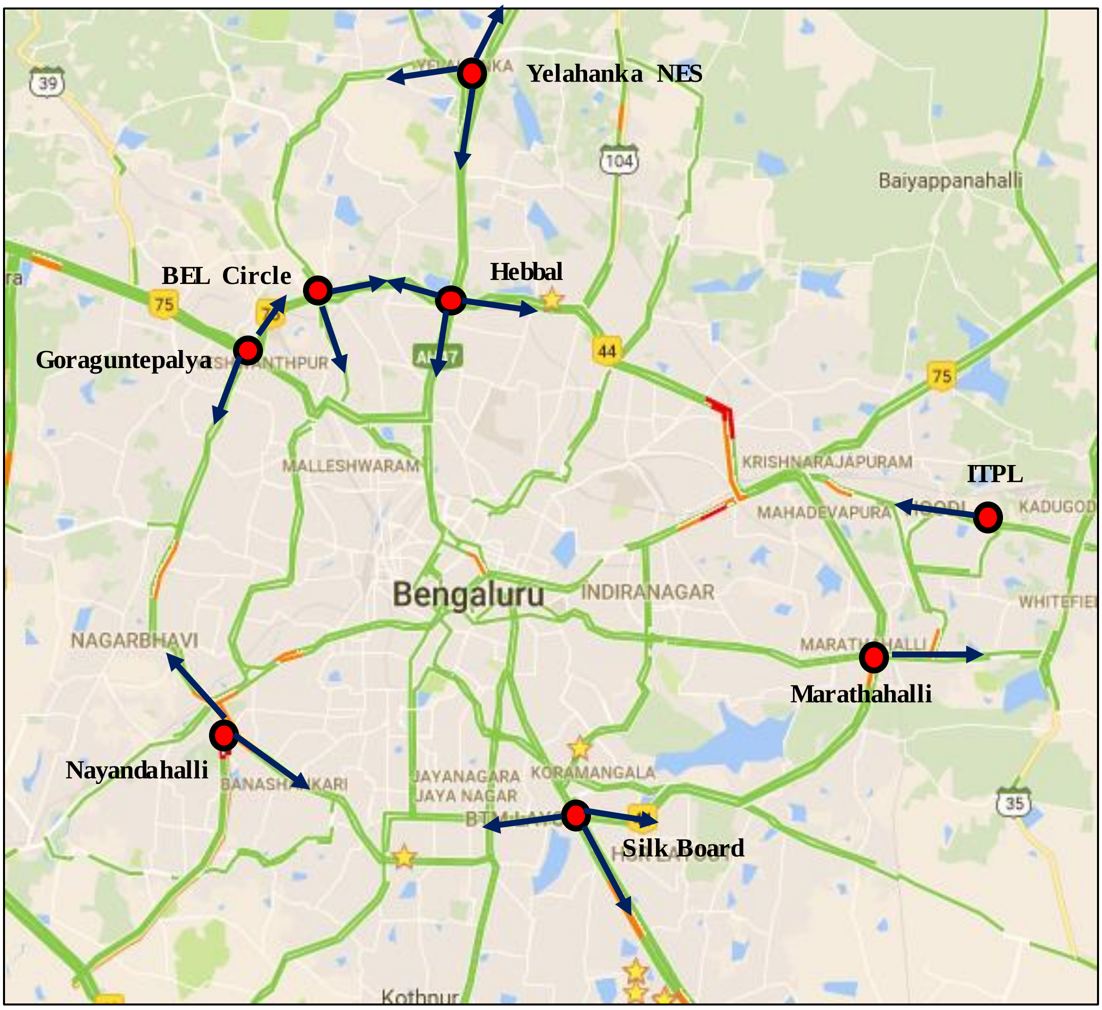

Figure 3: Survey location with direction

Table 1: Location, direction and mode-wise sample size distribution

Location	**Modal Share**							**Sample Size**	**Direction**	
	O. Bus	**P. Bus**	**Cab**	**TT**	**Car**	**Auto**	**TW**		**Towards**	**Sample Size**
Nayandahalli	150	150	50	50	100	100	200	800	Banashankari	400
									Goraguntepalya	400
Goraguntepalya	150	150	50	50	100	100	200	800	Outer Ring Road towards Hebbal	500
									Ring Road towards Nayandahalli	300
ITPL	150	150	50	50	100	100	200	800	Outer Ring Road / K. R. Puram	800
Yelahanka NES	150	150	50	50	100	100	200	800	Hebbal	300
									Peenya	300
									Doddaballapur	200
Central Silk Board	200	200	50	50	120	120	260	1,000	ITPL	400
									Electronic City	400
									Banashankari	200
Marathahalli Bridge	120	120	30	30	75	75	150	600	ITPL	600
Hebbal	200	200	50	50	120	120	260	1,000	K. R. Puram	300
									Tumkur Road	200
									City Centre	300
									Airport	200
BEL Circle	120	120	30	30	75	75	150	600	Majestic (via Mathikere)	300
									Hebbal	300
Total								6,400		

7.2. Type of Data Collected from Various Sources

The following data sets were collated from the primary and secondary data collected:

7.2.1. Secondary Sources

Secondary sources comprised a list of existing AC bus routes from BMTC (BMTC 2018a) (Refer Annexure II for data collection template).

7.2.2. Primary Sources

Primary sources involved commuter survey (of those using motorised modes of transport) to assess willingness to shift to AC bus services (except BMTC AC bus users):

- Travel pattern of commuters (origin-destination, mode of travel, trip purpose and frequency)
- Probability of shift to AC bus services: location-wise & mode-wise

7.3. Instruments for Data Collection

7.3.1. Secondary Sources

A data collection template was shared with BMTC and is provided in Annexure II.

7.3.2. Primary Surveys

For primary data collection, a structured survey questionnaire was used to capture the data. The questionnaire for this survey is given in Annexure III. Open Data Kit (ODK), an Android-based mobile app, was used to collect the primary data[3].

The commuter survey questionnaire comprised three sections:

1. Socio-economic information
2. Travel information
3. Scenarios (varying fare)

7.4. Protocols for Data Collection and Ethics Followed

Secondary data for the current study was collected from BMTC. Before conducting the primary field survey at major intersections, necessary permission letters were obtained from the Commissioner of Police (Bengaluru City) and BMTC. It was a voluntary survey, and care was taken to preserve the anonymity of the respondents. For example, no particular bus company was targeted for the private bus category; similarly, no particular class of two-wheelers / four-wheelers was targeted for the private vehicle category.

8. Data Collection

8.1. Primary Data – Commuter Survey

The structured questionnaire was discussed with BMTC and was revised to incorporate the suggested changes. This questionnaire was then tested by conducting a pilot survey at select locations (ITPL and Goraguntepalya). The pilot survey revealed that it was difficult to capture the travel cost per trip for private vehicle users (cars and two-wheelers). So, the travel cost for cars and two-wheelers was calculated based on the travel distance and fuel cost.

The survey was carried out at 8 locations from February 20, 2018 to March 2, 2018 on regular working days, covering around 6,400 samples. The respondents included ordinary BMTC bus

[3] https://opendatakit.org/

users, private bus users, cab users, Tempo Traveller users and private vehicle (cars, autos and two-wheelers) users.

The locations and directions at which the samples were to be collected were finalised based on discussions held with BMTC, and the survey was conducted using ODK. Specially trained field investigators and enumerators under the close guidance of supervisory staff were utilised for this purpose. The data thus collected was compiled and subjected to thorough verification and analysis. The data from the primary survey was extracted in MS Excel format. This data was then checked for completeness, invalid samples and data entry errors and considered for analysis.

8.1.1. Data Digitisation

Data digitisation consisted of plotting the origin and destination of respondents based on landmarks and locations collected during the survey. To achieve this, the GIS location (latitude and longitude) of the respondent is required. This is accomplished by a Python script, which fetches the passenger's landmark from the collected data set and uses the Google Maps Application Programming Interface (API) to get the required GIS information.

8.2. Data Analysis

8.2.1. Socio-Economic Profile of Respondents

The data collected through the survey showed that 65% of respondents were male and 35% were female (Figure 4). 55% of the respondents belonged to the age group of 19 to 30 years (Figure 5).

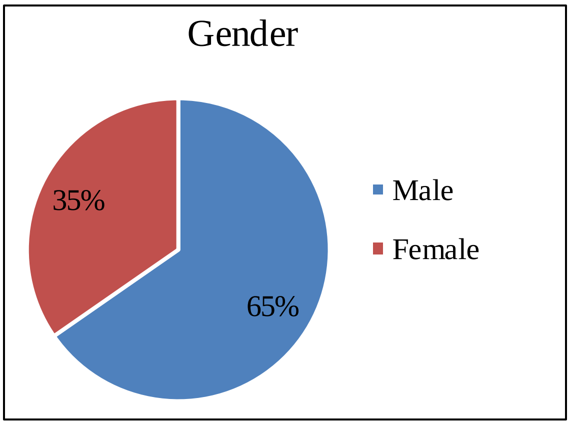

Figure 4: Gender of respondents

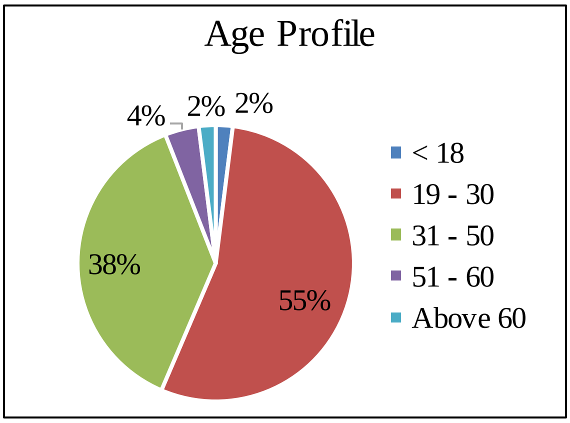

Figure 5: Age profile of respondents

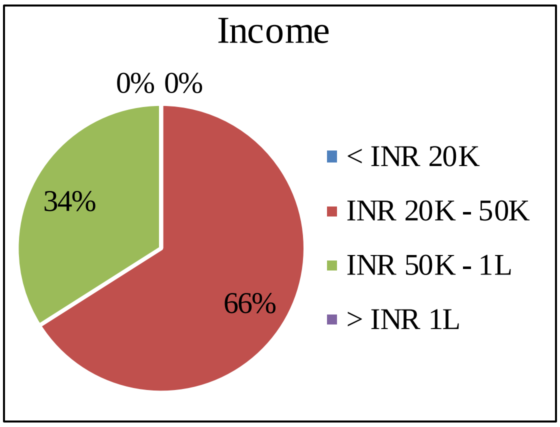

Figure 6: Income profile of respondents

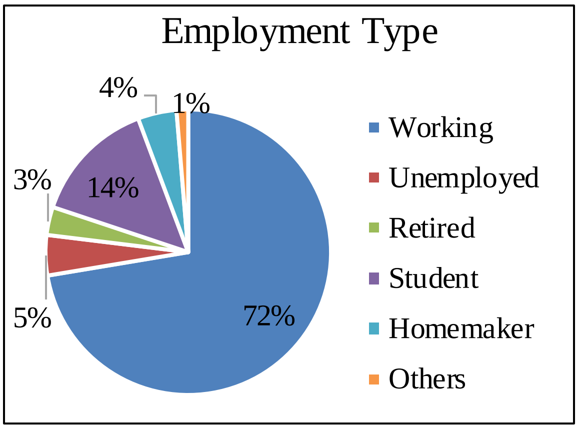

Figure 7: Employment profile of respondents

66% of the respondents (Figure 6) had a monthly HH income in the range of INR 20,000–50,000. 72% of the respondents were in the working group (Figure 7).

8.2.2. Purpose and Frequency of Travel

Of the total trips, 72% were work trips, while 15% were educational (Figure 8). In terms of frequency (Figure 9), a majority of the trips were daily trips (81%).

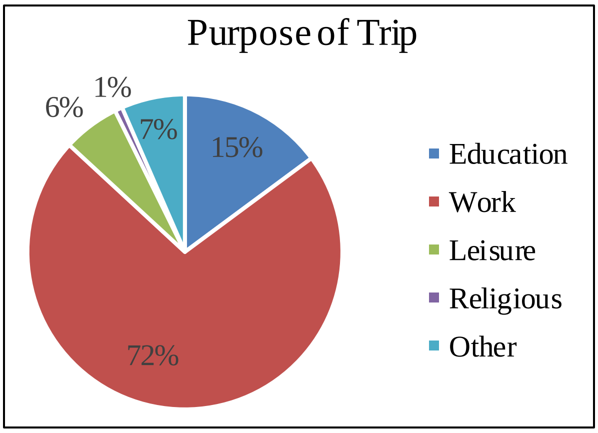

Figure 8: Purpose of Travel

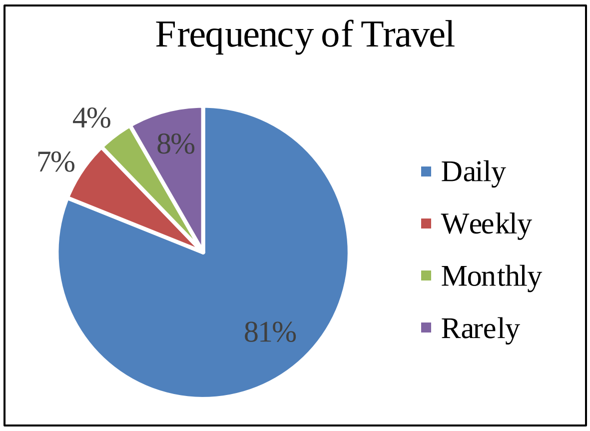

Figure 9: Frequency of Travel

8.2.3. Travel Pattern of Respondents

The commuter survey was conducted at major interchange locations in the city. Hence, the trip captured for each respondent is divided into two parts: from the origin to the survey location (origin trip) and from the survey location to the destination (destination trip). These trips were then plotted for further analysis. 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 10 represents the survey location, ward boundary and number, trips from the origin to the survey location and trips from the survey location to the destination. This desire line[4] diagram served as an input for understanding the direction of travel at the major survey locations.

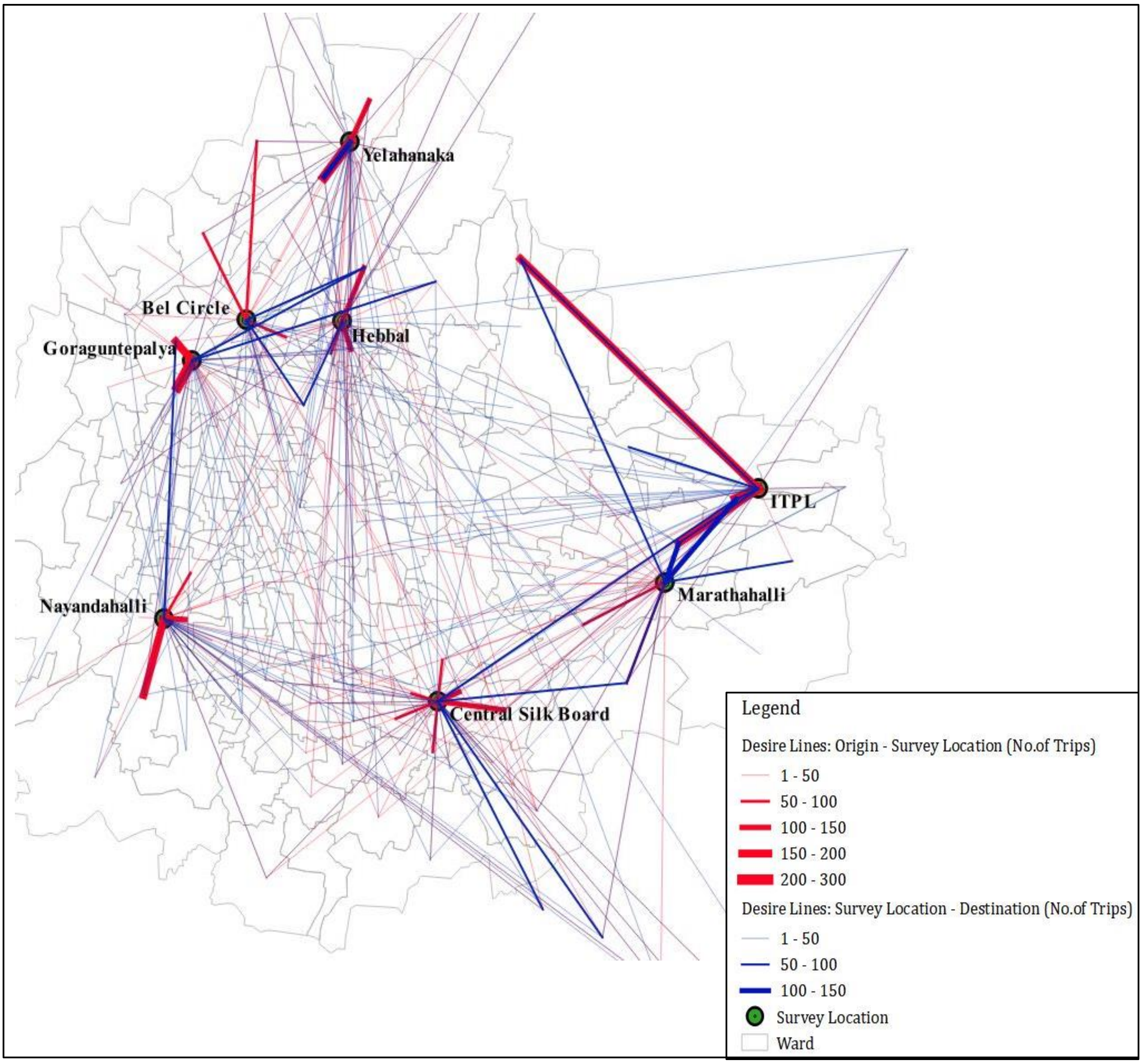

Figure 10: Origin – destination desire lines: All locations

[4] Desire line diagram connects two points (origin and destination) with straight lines; the thickness of the lines is typically proportional to the number of trips between the points.

Figure 11 shows origin trips (red lines) and destination trips (blue lines), to and from the survey location. The total number of trips (origin and destination) is over 50. The highest number of trips are from Rajarajeshwari Nagar to Nayandahalli Junction, HMT to Goraguntepalya, Yelahanka Satellite Town to Yelahanka Junction, Yelahanka Old Town to Yelahanka Junction and Amrutahalli to Hebbal.

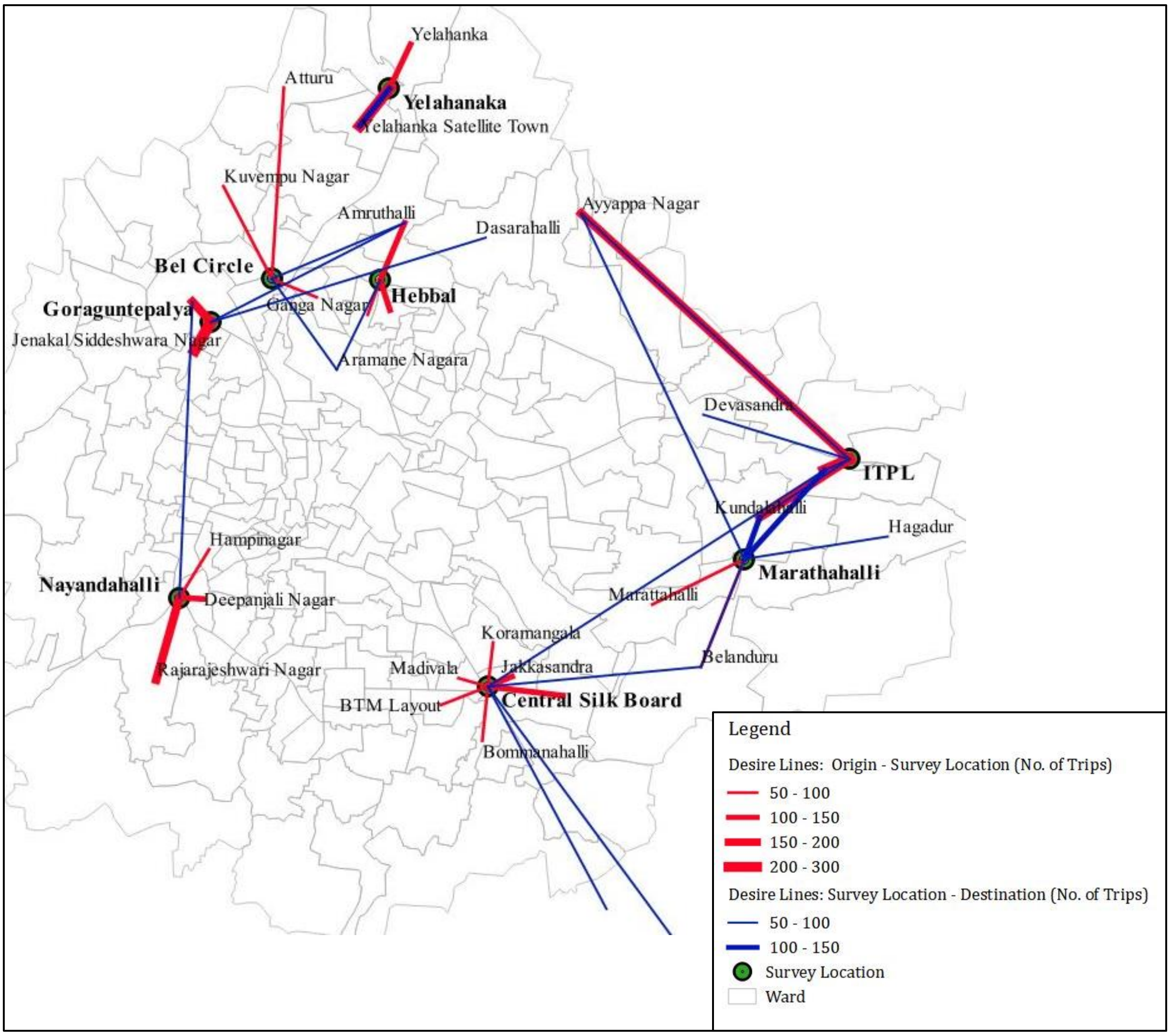

Figure 11: Origin – destination desire lines: Maximum trips

Table 2 shows the average trip characteristics (trip length, travel time and travel cost) for each mode. The average trip length was approximately 15 km and the average travel time was approximately 45 minutes, considering all modes. The average travel costs for cab and auto are very high.

Table 2: Average trip characteristics

Mode	Average Trip Length (km)	Average Travel Time (Min)	Average Travel Cost (INR)
BMTC Ordinary Buses	15.09	54	23
Private Bus / Tempo Traveller	13.25	44	24
Cab/Taxi	15.37	44	184
Auto	13.63	42	180
Private Car	17.03	48	68
Two-Wheeler	16.21	47	32

8.2.4. Relationship between Mode of Transport and Distance

Figure 12 shows the mode-wise trip length distribution. On an average, 45%–50% trips by all the modes are within a distance of 10–20 km.

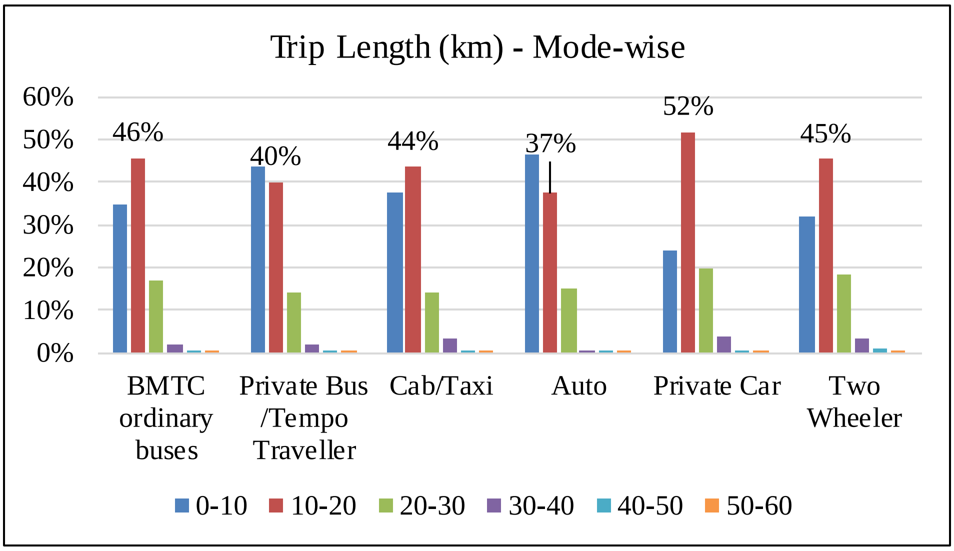

Figure 12: Relationship between mode of transport and distance

9. Findings and Discussion

Results of the detailed analysis are described in this section.

9.1. Willingness to Shift to AC Bus Services

In this study, the discrete choice model (DCM) was used to estimate the probability of shift from commuters' current mode of transport to AC bus services. The socio-economic data, travel characteristics data and willingness to shift to AC bus from current modes of transport (captured during the survey) served as inputs for the DCM. A detailed explanation of the DCM is given in Annexure IV.

To understand this shift, a multinomial logit discrete choice model (Koppelman and Bhat 2006) was developed using Biogeme[5] (Bierlaire 2017), considering the revealed preference[6] (RP) and stated preference[7] (SP) survey data (collected from the 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 two different scenarios.

Two scenarios based on travel cost were designed to understand the respondents' preferences. Details of the scenarios are given in Table 3.

Table 3: Scenario details

Scenarios	Travel Cost	Frequency
Scenario 1	Equivalent to existing AC bus fare	15 minutes
Scenario 2	20% reduction in existing AC bus fare	15 minutes

The expected willingness to shift to AC bus services from current modes of travel is shown in Table 4. Under both scenarios and for all locations, about 25% of the commuters are expected to shift to AC bus services. From Table 4, the maximum shift is expected from ITPL, BEL Circle, Nayandahalli and Marathahalli Bridge.

5 Biogeme is an open-source software product used to estimate discrete choice models.
6 Revealed preference survey: In this study, the RP survey captures the respondents' current mode of transport, that is, bus (ordinary or private bus), car, two-wheelers, auto and cab/taxi.
7 Stated preference survey: In this study, the SP survey captures the survey respondents' preferred mode of transport, between a given proposed mode of transport (AC bus) and their current mode of transport.

Table 4: Location-wise willingness to shift to AC bus service

Survey Location	Scenario 1	Scenario 2
BEL Circle	26%	27%
Central Silk Board	24%	24%
Goraguntepalya	23%	23%
Hebbal	24%	24%
ITPL	27%	27%
Marathahalli Bridge	26%	26%
Nayandahalli	25%	26%
Yelahanka NES	21%	22%

Table 5 represents the location-wise mode share with and without AC bus services under Scenario 1. The 'current mode share' in Table 5 is a representative combined mode share of all survey locations. This is based on the overall mode share of Bengaluru city. For example, at BEL Circle, the current mode share without introduction of AC bus services was 13% for car, 25% for two-wheeler, 13% for auto, 6% for cab, 19% for private bus and 25% for ordinary bus (which is same for all locations). The 'average estimated mode share' after introduction of AC bus is also shown in Table 5. The mode shift observed is the difference between the current mode share and the estimated mode share, the modal shift observed at this location was 4% from car, 7% from two-wheelers, 9% from auto, 4% from cabs, 1% from private bus and 1% from ordinary bus, thus arriving at a total modal share of 26% for AC bus services.

The maximum shift was observed from autos—a total of 8%. Two-wheeler commuters starting from locations such as ITPL, BEL Circle and Marathahalli Bridge show a high probability of shifting to new AC buses.

Table 5: Location-wise SP mode share: Scenario 1

Survey Location	Car	TW	Auto	Cab	Private Bus	Ordinary Bus	AC Bus
BEL Circle	9%	17%	5%	2%	18%	23%	26%
Central Silk Board	9%	19%	4%	2%	20%	22%	24%
Goraguntepalya	10%	17%	4%	2%	19%	26%	23%
Hebbal	9%	20%	5%	2%	18%	22%	24%
ITPL	9%	17%	5%	2%	17%	23%	27%
Marathahalli Bridge	10%	17%	4%	2%	18%	23%	26%
Nayandahalli	9%	17%	4%	2%	19%	24%	25%
Yelahanka NES	10%	19%	4%	2%	18%	26%	21%
Current Mode Share	13%	25%	13%	6%	19%	25%	0%
Average Estimated Mode Share	9%	18%	4%	2%	18%	24%	25%
Mode Shift	4%	7%	9%	4%	1%	1%	NA

Table 6 represents the location-wise mode share when AC bus services were introduced under Scenario 2. The current mode share is based on the overall mode share of Bengaluru city. The table also shows average estimated mode share (for all locations) after introduction of AC bus services at these locations. The current mode share and the average estimated mode share were compared for further analysis. The maximum shift (from 13%, current mode share to 4%, average estimated mode share) was observed from autos. The second highest shift was observed from two-wheelers (from 25%, current mode share to 18%, average estimated mode share). Two-wheeler and auto commuters starting from locations such as ITPL, BEL Circle, Marathahalli Bridge and Nayandahalli show a high probability of shifting to new AC buses.

Table 6: Location-wise SP mode share: Scenario 2

Survey Location	Car	TW	Auto	Cab	Private Bus	Ordinary Bus	AC Bus
BEL Circle	10%	17%	5%	2%	17%	23%	26%
Central Silk Board	9%	19%	4%	2%	20%	22%	24%
Goraguntepalya	9%	17%	4%	2%	19%	26%	23%
Hebbal	10%	20%	4%	2%	18%	22%	24%
ITPL	9%	17%	5%	2%	17%	23%	27%
Marathahalli Bridge	10%	17%	4%	2%	18%	23%	26%
Nayandahalli	9%	17%	4%	2%	19%	23%	26%
Yelahanka NES	10%	19%	4%	1%	18%	26%	22%
Current Mode Share	13%	25%	13%	6%	19%	25%	0%
Average Estimated Mode Share	10%	18%	4%	2%	18%	23%	25%
Mode Shift	3%	7%	9%	4%	1%	2%	NA

For scenario 2, the current mode share and the average estimated mode share were compared for further analysis. The maximum shift (from 13%, current mode share to 4%, average estimated mode share) was observed from autos. The second highest shift was observed from two-wheelers (from 25% current mode share to 18%, average estimated mode share). The mode shift observed is the difference between the current mode share and the estimated mode share, the modal shift observed at this location was 3% from car, 7% from two-wheelers, 9% from auto, 4% from cabs, 1% from private bus and 2% from ordinary bus.

The following observations were made from the study:

- 25% of the respondents were willing to shift to AC bus services from their current mode of transport.
- Of the 8 locations surveyed, the maximum willingness to shift was observed from ITPL, BEL Circle, Marathahalli Bridge and Nayandahalli.

- The majority of the shift to AC bus services was from commuters using autos and two-wheelers.
- There was minimal shift from ordinary buses and private buses.

9.2. Potential Direction for AC Bus Services

Based on the DCM results and desire line diagram, the following locations were identified as feasible for introducing new AC bus services:

- ITPL
- BEL Circle
- Hebbal
- Marathahalli
- Nayandahalli

ITPL and Marathahalli, which are well connected with BMTC AC bus routes, are not considered for further analysis. Wards that have the highest demand (attract and generate the most trips) were identified around each survey location to determine the feasible direction for operating AC bus services. The location-wise potential direction of travel for BEL Circle and Yelahanka are represented in Figure 13 and Figure 14.

The number of trips originating from and terminating at each ward was identified for Hebbal, as shown in Figure 13. Most of the trips originate at close proximity to the survey location, as well as in Yelahanka. The feasible direction of service for Hebbal could be towards the north, because a significant number of trips are observed from Yelahanka and Yelahanka Satellite Town.

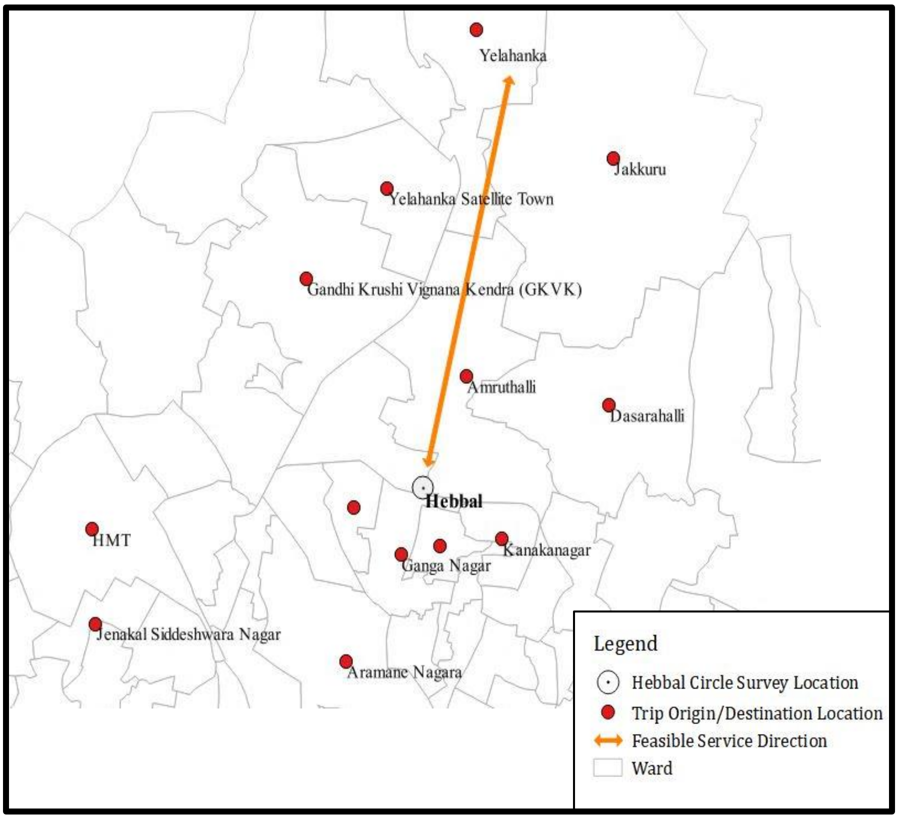

Figure 13: Feasible direction of new AC bus service, Hebbal

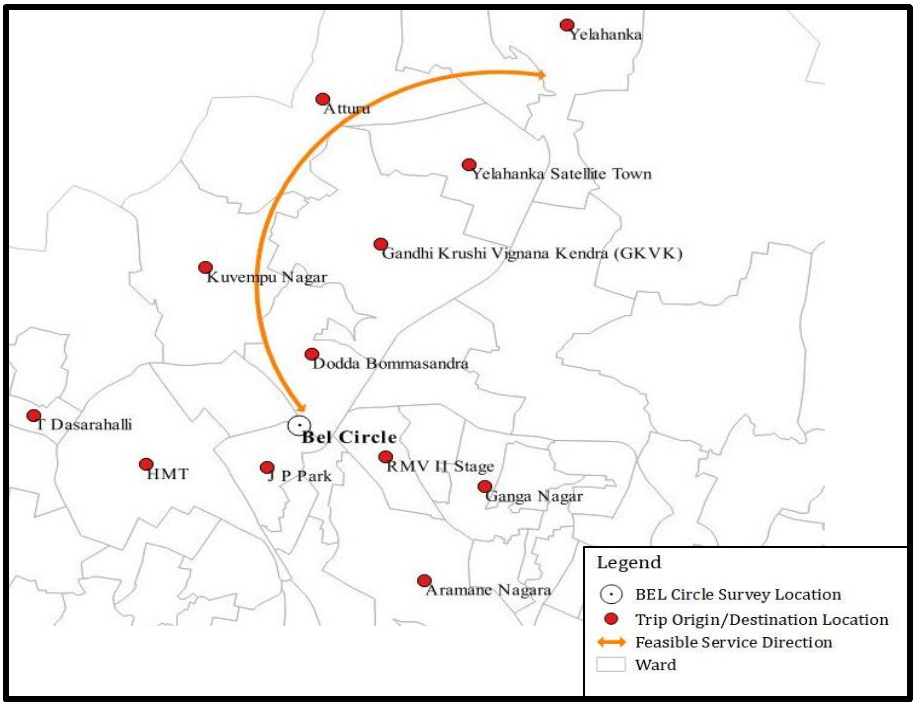

Figure 14: Feasible direction of new AC bus service, BEL Circle

The number of trips originating from, and terminating at, each ward were also identified for BEL Circle, as shown in Figure 14. Most of the trips originate around Yelahanka. The feasible direction of AC bus services for BEL Circle could be towards Yelahanka via Kuvempu Nagar and Atturu.

The survey analysis reveals that several trips are originating and terminating at Amruthahalli. Hence further analysis of Amruthahalli was carried out. Figure 15 below shows trips terminating at Amruthahalli have their origins at Yelahanka, Yelahanka Satellite Town, HMT and Jenakal Siddeshwara Nagar. Similarly, Figure 16 shows trips originating at Amruthahalli have their destinations at Yelahanka, Yelahanka Satellite Town, HMT and Aramane Nagar. Hence the feasible route for BMTC could be Yelahanka – Yelahanka Satellite town – Amruthahalli – Hebbal – BEL circle – HMT (~15km).

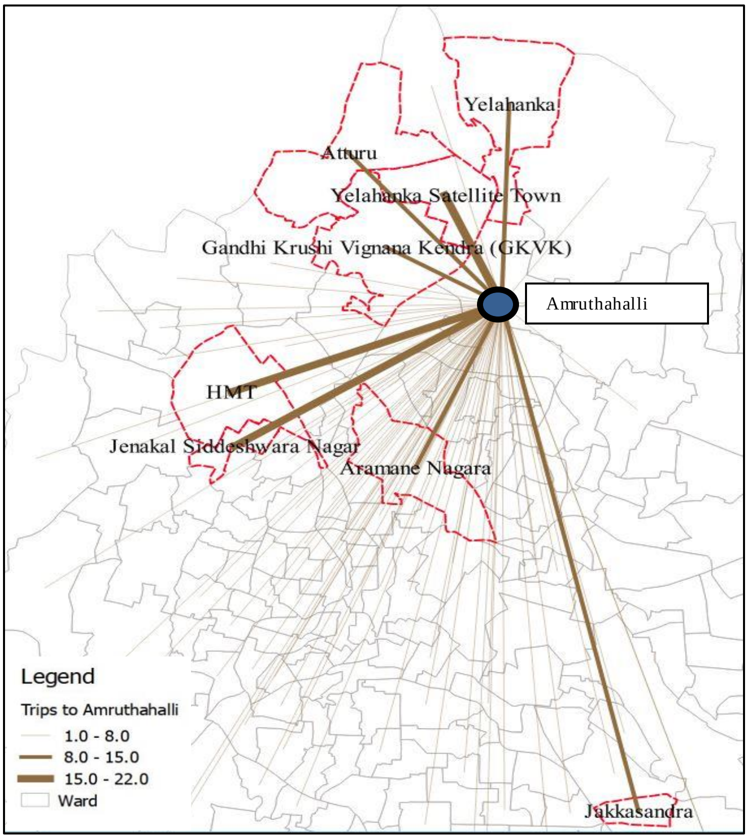

Figure 15: Trips terminating at Amruthahalli

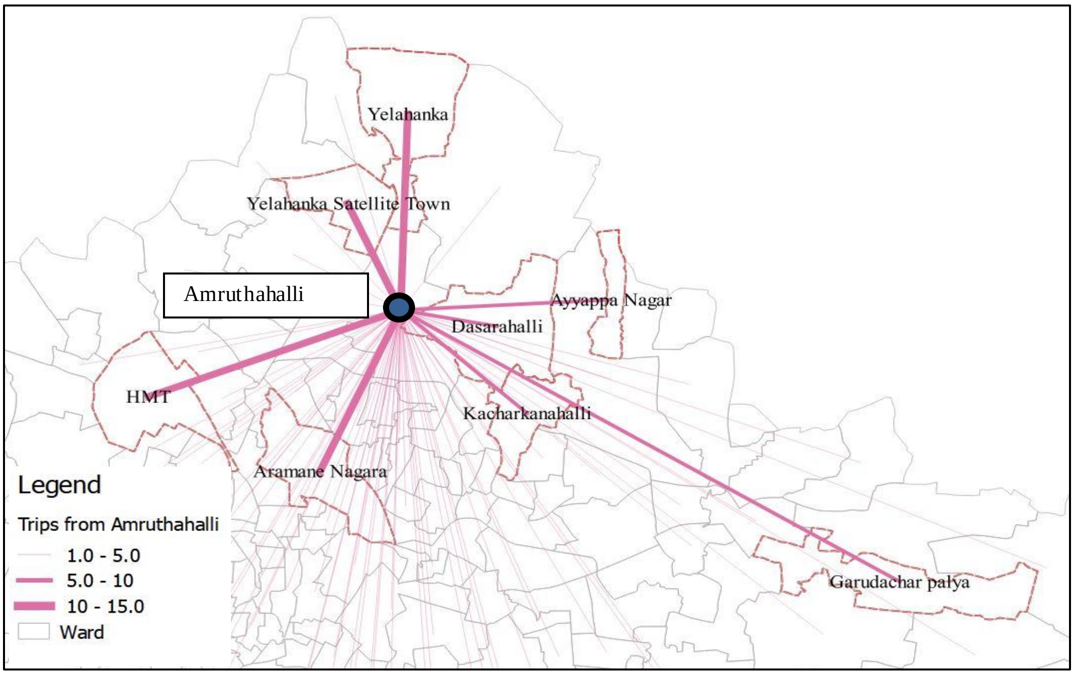

Figure 16: Trips originating at Amruthahalli

10. Conclusion

In this study, commuter survey was conducted at eight major junctions in Bengaluru. The survey captured socio-economic characteristics and trip characteristics of private vehicle users (TW and car), bus users (ordinary and private) and intermediate public transport (IPT) users (auto and cab). The survey determined users' willingness to shift to AC bus under two different scenarios (with varying travel cost). DCM was used to analyse the location-wise probability of shift from respondents' current mode of transport to AC bus. Wards with the highest demand (that attract and generate the most trips) were studied to identify the routes and direction for the new AC bus services.

The study determined that commuters using IPT (auto) and two-wheelers display the greatest willingness to shift to AC buses, both at the current ticket rates and after a 20% fare reduction. On the other hand, commuters who use private buses or non-AC BMTC buses are not willing to shift to AC buses, even after 20% fare reduction.

11. Recommendations

A trial AC bus service can be operated in the directions suggested from the analysis. This will help understand the actual demand for such services. This study can serve as a basis to identify potential areas and routes to introduce AC bus services.

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Annexure I

Sample Size Calculation

The minimum sample size required for an infinite population will be as follows (Sarmah and Hazarika 2012);

$$n_0 = \frac{Z^2 \times p(1-p)}{e^2}$$

Where

n_0 = Sample Size

Z = Z Score Value

e = Margin of Error

p = Prior Judgment of the Correct Value (Probability)

Taking a confidence level of 95% with a margin of error of ± 5%, probability of 50% and Z Score value of 1.96, the required sample size will be

$$n_0 = \frac{(1.96)^2 \times (0.5)(1-0.5)}{(0.05)^2}$$

= ~384

Taking the confidence level as 99% with a margin of error of ± 5%, probability of 50% and Z Score value of 2.58, the required sample size will be

$$n_0 = \frac{(2.58)^2 \times (0.5)(1-0.5)}{(0.05)^2}$$

= 665.64

= ~ 666

Annexure II

Data Collection Template

Route No.	Origin	Destination	No. of Schedules

Annexure III

Commuter Survey

(At specific locations)

Purpose: To determine the willingness of passengers to shift to AC bus services

Do you use AC bus services? Yes/No

Survey Location: Direction: ______ Date & Time:

Name ______________________ Phone Number ___________

Passenger Information

Gender

Male	Female

Age group

Less than 18 years	19–30 years	31–50 years	51–60 years	Above 60 years

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

Monthly household income:

Less than INR 20,000	INR 20,000–50,000	INR 50,000 – 1,00,000	More than INR 1,00,000

Travel Information

2. What is the mode of travel?

BMTC Ordinary Buses (Route No. . . .)	Private Bus / Tempo Traveller	Cab/Taxi ________	Auto	Private Car	TW	Others ________

3.

Origin: landmark and PIN code	Destination: landmark and PIN code
Boarding point (bus users)	Alighting point (bus users)

4. Purpose of travel:

Education	Work	Leisure	Religious	Other

5. How often do you make this trip?

Daily	Weekly	Monthly

6. i) Total travel time (including waiting time; in minutes):

____

ii) Total travel distance (km):

____

iii) Total travel cost (INR):

____

7. What is your preferred boarding time?
   i) Onward Journey _____________________
   ii) Return Journey _____________________

Willingness to Shift

8. What will encourage you to use AC bus service?

Scenario	Current Mode Travel Time	Current Mode Travel Cost	AC Bus Travel Time	AC Bus Travel Cost	Your Response	
					Current Mode	**AC Bus**
1	---	----	IVTT+15+10	X_1		
2	---	----	IVTT+15+10	X_2		

IVTT: In-Vehicle Travel Time
15 min – Frequency of AC bus
10 min – Waiting time at the bus stop
Suggestion: _____________________________________

Annexure IV

Discrete Choice Model

The study developed a multinomial logit model (MNL) to understand commuters' willingness to shift to AC bus services from their current modes of transport, based on their SP and RP survey (commuter survey). The socio-economic data, travel characteristics data and willingness to shift (captured in the survey) served 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 that 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 two scenarios and asked to choose between the given mode (AC bus) and their current mode of access. The scenarios based on travel cost (considered for the study) are shown in Table 3.

Travel time for the proposed AC bus was considered based on in-vehicle time and out-vehicle time. The in-vehicle time was estimated by dividing the distance between respondents' 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 the waiting time at the bus stop (based on the frequency of buses).

Travel time and travel cost for car, two-wheelers, auto, cab, private bus and ordinary bus were also calculated based on the in-vehicle travel time stated above. Travel costs for two-wheelers and cars were based on the fuel price and mileage of the respective modes. For auto, the fare was calculated by considering a minimum charge of INR 25 for the first 2 km and INR 13 for each additional km (travel2karnataka 2017). For cab and private bus, average fare per km was calculated based on the travel cost determined from the RP survey. For bus, fare was considered from the BMTC stage-wise fare data (BMTC 2018b).

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 the current mode of travel and BMTC AC bus.

The utility function for each alternative in RP and 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-wheelers were considered as the base or reference alternative, so the ASC of two-wheelers was fixed at zero.

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

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

Estimated Parameters

The model considered data from 19,720 responses [considered only respondents who had responded to RP (6,574 responses) and both scenarios under SP (13,146 responses)]. 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 with the utility, and a negative value indicates an inverse correlation (Bajracharya 2008). Negative signs of travel time and travel cost indicate that higher the travel time and cost, lower is the probability of choosing that alternative.

Table 7: Estimated parameters from MNL model

Name	Value	Std. Error	t-test	p-value
ASC_AC_SP	3.16	0.14	22.61	0
ASC_AUTO_RP	0	fixed		
ASC_AUTO_SP	0	fixed		
ASC_BUS_RP	1.06	0.0855	12.42	0
ASC_BUS_SP	2.34	0.134	17.43	0
ASC_CAB_RP	-2.29	0.136	-16.77	0
ASC_CAB_SP	-2.46	0.161	-15.28	0
ASC_CAR_RP	-0.994	0.0928	-10.7	0
ASC_CAR_SP	-0.0126	0.101	-0.13	0.9
ASC_PB_RP	0.816	0.0875	9.33	0
ASC_PB_SP	2.06	0.127	16.27	0
ASC_TW_RP	-0.109	0.0857	-1.27	0.21
ASC_TW_SP	0.872	0.111	7.87	0
B_COST	-0.113	0.03	-3.76	0
B_INCOME_BUS	-0.125	0.0119	-10.55	0
B_INCOME_CAB	0.17	0.0207	8.23	0
B_INCOME_CAR	0.0527	0.0132	3.98	0
B_INCOME_PB	-0.122	0.0126	-9.68	0
B_INCOME_TW	-0.0437	0.0117	-3.74	0
B_TIME	-4.61	0.155	-29.77	0
LAMBDA	0.884	0.0366	24.15	0

Example for DCM:

Illustrating an example from Chandra Bhat (2006), 'A Self Instructing Course in Mode Choice Modelling: Multinomial and Nested Logit Models'.

This example considers three mode choices - Drive Alone, Shared Ride and Bus available to an individual. Assuming the utility of individual depends on three factors: Travel Cost (TC); In-vehicle Travel Time (IVT) and Out-vehicle Travel Time (OVT), the Utility equation is formed as:

$$V_{DA} = \alpha_{DA} + \beta_{cost} \times TC_{DA} + \beta_{IVT} \times IVT_{DA} + \beta_{OVT} \times OVT_{DA}$$

$$V_{SR} = \alpha_{SR} + \beta_{cost} \times TC_{SR} + \beta_{IVT} \times IVT_{SR} + \beta_{OVT} \times OVT_{SR}$$

$$V_{BUS} = \alpha_{BUS} + \beta_{cost} \times TC_{BUS} + \beta_{IVT} \times IVT_{BUS} + \beta_{OVT} \times OVT_{BUS}$$

Where

V_j is the utility of the mode j (Drive Alone, Shared Ride and Bus)

α_j is the ASC for the moje j

β_{cost}, β_{IVT}, β_{OVT} are the weights associated with the travel cost, in-vehicle travel time and out vehicle travel time respectively.

Assuming following values for the parameters:

Mode	$\boldsymbol{\alpha}$	$\boldsymbol{\beta_{cost}}$	$\boldsymbol{\beta_{IVT}}$	$\boldsymbol{\beta_{OVT}}$
Drive Alone	0	-0.4	-0.031	-0.062
Shared Ride	-1.90	-0.4	-0.031	-0.062
Bus	-0.80	-0.4	-0.031	-0.062

To illustrate the application of the multinomial logit model for the above utility equation, we assume travel time and travel cost values as follows:

Mode	**IVT**	**OVT**	**Travel Cost**
Drive Alone	21 minutes	4 minutes	$1.75
Shared Ride	23 minutes	5 minutes	$0.75
Bus	25 minutes	30 minutes	$1.25

The probability equations for an individual for all the modes are given as:

$$P_{DA} = \frac{\exp(V_{DA})}{\exp(V_{DA}) + \exp(V_{SR}) + \exp(V_{BUS})}$$

$$P_{SR} = \frac{\exp(V_{SR})}{\exp(V_{DA}) + \exp(V_{SR}) + \exp(V_{BUS})}$$

$$P_{BUS} = \frac{\exp(V_{BUS})}{\exp(V_{DA}) + \exp(V_{SR}) + \exp(V_{BUS})}$$

Therefore the probability values for each mode are computed as following

Mode	Utility Expression	Value	Exponent	Probability
Drive Alone	-0.031×21 -0.062×4 -0.4×1.75	-1.599	0.202	0.773
Shared Ride	-1.90 -0.031×23 -0.062×5 -0.4 × 0.75	-3.223	0.040	0.152
Bus	-0.80-0.031×25-0.062×30-0.4×1.25	-3.935	0.020	0.075

The following result suggests that Probability of an individual to choose Drive Alone mode, Shared Ride and Bus is 0.773, 0.152 and 0.075 respectively.

Hence this particular individual will prefer Driving alone as his mode