Evaluation of Bus Rapid Transit System Based on Ridership Analysis: A Case Study of Ahmedabad Janmarg BRTS

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Erratum of MSc Thesis (Md Rabiul Islam- s1555235)

1. In page 39 and 40, one land use map was repeated. First one should be deleted.

Evaluation of Bus Rapid Transit System Based on Ridership Analysis: A Case Study of Ahmedabad Janmarg BRTS

by

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Abstract

BRTS (Bus Rapid Transit System) has been adopted in many countries in the world due to its unique characteristics for promoting sustainable mobility. It has also increasing effects on reducing automobile usage. In line with this assumption, the city of Ahmedabad, which is experiencing rapid economic growth and urbanization along with motorized mode especially motor-scooter, has introduced the BRTS in October, 2009. Though it has achieved widespread accolades, due to some reasons it could not achieve the maximum ridership. A ridership framework is thus required in order to assess the ridership performance to identify the influencing factors for this situation.

Firstly, a user analysis has been conducted to have insights about the socio-economic and travel behavior of the user. The outcome of this analysis enabled the researcher to identify possible factors from user socio-economic and travel behavior characteristics that are influencing BRTS ridership. Moreover, mode choice analysis using binary logistic method was also developed between the BRTS and AMTS user to check their mode choice variability for the selected factors. In brief, high fare structure in BRTS was one of the reasons for not being able to attract the low income people of the region. However, workers prefer BRTS rather than AMTS due to its better service quality. Possible strategies were developed afterwards to encourage the poor to BRTS. Simultaneously, further research on the Stated Preference survey on households along the BRTS corridor was also emphasized.

Secondly, ridership model was developed based on the commonly used built form indicators (5D) which were expected to have significant influence on ridership performance. But it was found totally missing for Ahmedabad BRTS context. Among the built-form indicators, job accessibility, road connectivity and land use diversity were found to be in poor condition. This has created the need of inclusion of socio-economic variables in the ridership model. But this is beyond the scope of this research due to data unavailability. Several policy recommendations were suggested along the BRTS corridor in line with the existing policy like utilization of full FSI by applying TOD strategy, increase of accessibility to BRTS through integration of non-motorized mode.

Keywords: BRTS, Ridership, Mode choice, Built-form, Entropy, Binary Logistic, Multiple Regression

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Best Regards.

Md Rabiul Islam
February, 2016

Table of Contents

List of Figures

List of Tables

List of Acronyms

AMC- Ahmedabad Municipal Corporation
AMTS- Ahmedabad Municipal Transport Service
AUDA- Ahmedabad Urban Development Authority
BRT- Bus Rapid Transit
BRTS- Bus Rapid Transit System
CBD- Central Business District
CEPT- Centre for Environmental Planning and Technology
EWS- Economically Weaker Section
FSI- Floor Space Index
GIDB- Gujarat Infrastructure Development Board
INR -Indian Rupee
ITC- Institute of Geo-information Science and Earth Observation
ITDP -Institute for Transportation and Development Policy
LIG- Low Income Group
MIG- Middle Income Group
OLS-Ordinary Least Square
ROW-Right of Way
RP- Revealed Preference
TAZ- Traffic Analysis Zone
TOD- Transit Oriented Development

1 Introduction

This chapter is to introduce the study background followed by the research problem and formulation of appropriate research objectives and questions. Finally it will guide the reader towards the development of a proper research structure.

1.1 Background and Justification

Bus Rapid Transit (BRT) systems have been adopted in many cities of the world due to their unique characteristics of mass transit for promoting sustainable mobility and as a key strategy for relieving traffic related problems, mainly congestion (Deng & Nelson, 2013). BRT aims to reduce automobile usage and thus making a city least liable to environmental damage, for example by reducing vehicle emissions (Deng, Ma, & Wang, 2013).

The city of Ahmedabad, the seventh largest city in India and the largest in the state of Gujarat, is experiencing rapid economic growth and urbanization, thus emerging to be one of the main urban centers of India. Ahmedabad had its strong base in the cotton textile industry which has developed the city to be an attractive destination for investment. It is a compact city with a mixed pattern of land use across its 490 square km area. It accommodates over 5.6 million people and is expected to grow up to 11 million by 2035 (Bajracharya, Zuidgeest, Brussel, & Munshi, 2008; Shastry, 2010).

To fulfill the transport demand of this large population, a substantial number of motorized vehicles are in use. The city has registered 1.4 million vehicles, a number which is growing at a rate of 8-10% (0.1 million) per year. This rapid growth in automobiles, where two wheelers (motor scooter) account for 73% of the total share, four wheelers (car) and three wheelers account for around 12.5% and 5.01% respectively, has resulted in congestion and air pollution. As a result, the city of Ahmedabad was figured as one of the top 3 cities in the list of 88 critically polluted cities of India (National Institute of Urban Affairs, 2011).

Furthermore, the city has also experienced an increasing accident rate. A study conducted in 2008 in cooperation with AMC, AUDA and CEPT University indicated that out of 2,605 accidents 9.5% were fatal and in 42% of cases the victims were cyclists and in 19% percent of cases they were pedestrians. Besides, due to resource crunch and operational inefficiencies, the Ahmedabad Municipal Transport Service (AMTS), the only public transport that is run by the city authority, has reduced its fleet size from 724 to 540 buses, while the number of passengers also dropped to 0.35 million from 0.62 million (Mahadevia, Joshi, & Datey, 2013).

In order to resolve those issues along with reducing automobile dependence (e.g., motor scooter, auto rickshaw and car) and keeping pace with the increasing demand, the city has introduced the Janmarg Bus Rapid Transit System (BRTS) in October 2009, which was designed as a complementary mode for the AMTS. The project was to be undertaken in 3 phases. The 1st and 2nd phase of Janmarg BRTS are already in operation and the 3rd phase is currently under construction which will develop a connection between other city regions (Mahadevia, Joshi, & Datey, 2013).

Janmarg BRTS has been designed by following some ideologies, for example connecting to low income zones, to low accessibility zones and to busy places, but avoiding busy roads. Availability of Right of Way (ROW) is also an important consideration for designing the system. The aim of the BRTS design was to ensure the mobility and proper accessibility for the people in the city area through the increase of speed, ridership, and service area (National Institute of Urban Affairs, 2011).

Since its launch, Janmarg BRTS has earned worldwide acclaim and is considered as a role model in the public transportation sector in India. Janmarg BRTS is the first BRT system in India that has achieved a Silver rating, scored between 70 to 84 on a scale of 100, in the BRT standard score developed by ITDP (Institute for Transportation and Development Policy). The standard score is derived from 5 criteria namely dedicated Right-of-Way, bus way alignment, off-board fare collection, intersection treatment, and platform-level boarding (Institute for Transportation and Development Policy, n.d.). It has also managed quite a high ridership (passengers per day) as statistics of Ahmedabad Municipal Corporation (AMC) in 2011 show that on average 0.13 million passengers use this BRT service daily and the daily revenue is about 0.75 million INR (Indian Rupee) (National Institute of Urban Affairs, 2011). Besides, its modal share has also increased significantly.

A survey was carried out by Mahadevia in 2012 on BRTS to observe the modal shift of BRTS from other modes where it was found that 47% of BRTS user shifted from the AMTS which ran along the BRTS corridors prior to BRTS implementation, another 25% shifted from auto rickshaws, 11.7% from private vehicle, and only 2.3% from walking and cycling. The remaining 13% users have been encouraged to travel due to its better service quality. Since modal share has reduced significantly for other modes thus helping to reduce motorized mode (Mahadevia, Joshi, & Datey, 2012) cited in (Rogat, Dhar, Joshi, Mahadevia, & Mendoza, 2015).

Despite of having a worldwide reputation, some contentious issues have been raised up towards Janmarg BRTS. In the same study mentioned above, Mahadevia pointed out some of the issues: the level of service meets only 1% of travel demand of 30 billion passenger km, only 27% of BRTS users are women, only 3% of trips are made by the low-income groups of the society, it has not been fully integrated with AMTS (Ahmedabad Municipal Transport Service), and footpaths and cycle tracks have not been designed and built along all corridors thus hampering safety and access of the pedestrians and cyclists to BRTS station (Mahadevia, Joshi, & Datey, 2012). Although BRTS has created new demand and enhanced people’s mobility, it failed to develop dedicated commuters of working class people (Tiwari, Mohan, Rao, Mahadevia, & Joshi, 2011). A case study by Damor, Kumara, & Hajiani (2014) have found out that in the corridor Kalupur station to Town hall station, commuters are not using BRTS, rather they prefer AMTS and other modes. It is because commuters find it difficult to access to BRTS due to lack of provision of pedestrian crossing. High fare structure of BRTS for short distances in comparison to AMTS was also one of the reasons behind it.

The issues discussed above directly or indirectly hamper the ridership (passengers per day) performance. Ridership performance may be influenced by factors such as comfort, safety, capacity, fare, speed, frequency and so on. Those service factors can be termed as internal factors but there exist some external factors along the corridor of BRTS such as population density, employment density, distance to nearest bus stop, accessibility and so on which may also impact on ridership performance.

In the detailed report on Janmarg BRTS, (Ahmedabad Municipal Corporation, 2008a) which was fully planned and designed by the technical team from CEPT University, one of the visions was to ensure full accessibility of Janmarg BRTS to all class of people. After addressing the low level of public transit patronage (ridership), it has put more importance for developing a market for public transit which can maximize the ridership by serving the need of people. Besides, increase of ridership can help in reducing the automobile dependence (two wheelers, car) which have impacts on congestion reduction and on pollution reduction (Ahmedabad Municipal Corporation, n.d. ; Ahmedabad Municipal Corporation, 2008b).

In brief, it can be said that Janmarg BRTS could not achieve yet the maximum ridership which intends the researcher to assess the ridership performance of Janmarg BRTS. Alternatively, it can be said that it is the prime task of this research to find out the factors which are influencing the ridership to a large extent.

1.2 Research Problem

The aim of the City authority (AMC) is to maximize the ridership of BRTS. However, no in-depth study was found on the ridership analysis of Janmarg BRTS or there is no framework yet developed for uncovering the reasons behind the low ridership of this mode. Therefore in this study, relevant studies regarding ridership analysis will be used as references in order to develop a conceptual framework for exploring the case of Ahmedabad BRTS. Significant factors (internal or external) that affect the ridership performance will be explored and the results from the analysis will be used to reflect on policy guidelines on the improvement of this system.

1.3 Objectives and Questions

The main goal of the study is to develop a framework to evaluate the performance of Janmarg BRTS in the context of ridership analysis.

Specifically, some objectives and research questions are then formulated:

1. To develop a user analysis for Ahmedabad Janmarg BRTS.
   - What are the socio-economic and trip characteristics of BRTS and AMTS users?
   - What are the key factors that have significant influence on the mode choice?
2. To conduct the ridership analysis using the built-form indicators.
   - What are the appropriate measures for each indicator?
   - What are the indicators that have significant influence on ridership?
   - What is the prediction accuracy of the ridership model?
3. To develop a policy recommendation for Janmarg BRTS in line with the existing policy.
   - What are the existing policies of Janmarg BRTS?
   - What are the policy recommendations that can be taken into account to improve the BRTS ridership?

1.4 Research Structure

The structure of this research is presented in the following Figure 1-1 . It summarizes the flow of the whole research from problem identification to conclusion. This research is mostly based on primary data that will be collected from the field through a user questionnaire survey at the station level. In addition, data about neighborhood characteristics will be used in order to identify the influence of BF (built-form) indicators on ridership. Final output will be assessed and discussed in line with the research questions. The report will be finalized after adding some policy guidelines on Janmarg BRTS and scopes for future research. Besides, literature review will continue during the entire period of the study. More will be discussed about the approach and methodology in Chapter 4 after developing some deep insights through literature review.

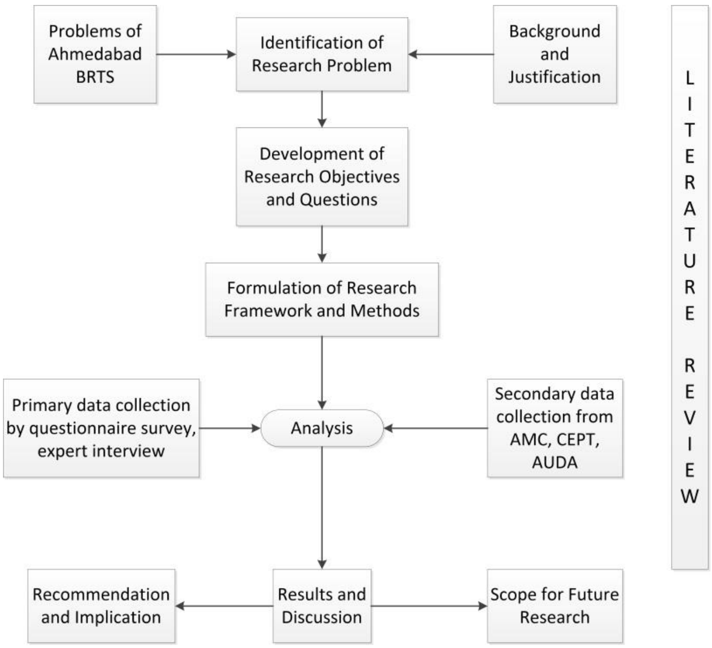

Figure 1-1: Research Structure

1.5 Research Matrix

The following Table 1-1 shows research design matrix which explains data source, techniques of analysis and anticipated result that will be used for answering research questions.

Table 1-1: Research Matrix of this study

Objective	Research question	Data source	Techniques of analysis	Anticipated result
To develop a user analysis for Ahmedabad Janmarg BRTS	- What are the socio-economic and trip characteristics of BRTS and AMTS users? - What are the key factors that have significant influence on the mode choice?	BRTS and AMTS user survey at stations	Descriptive analysis and binary logistic analysis	Identification of socio-economic and trip characteristics of the user that are substantive for BRTS ridership
To conduct the ridership analysis using the built-form indicators	- What are the appropriate measures for each indicator? - What are the indicators that have significant influence on ridership? - What is the prediction accuracy of the ridership model?	Archive of ITC, CEPT, AMC and AUDA for data collection, and literature review to find out the appropriate methods and techniques	Use of SPSS for performing analysis such as regression analysis, multicollinearity analysis and so on. Use of GIS for mapping.	Indicators having significant influence on ridership will be identified
To develop a policy recommendation for Janmarg BRTS in line with the existing policy.	- What are the existing policies of Janmarg BRTS? - What are the policy recommendations that can be taken into account to improve the BRTS ridership?	Results and findings from the analysis, Existing policy reports from CEPT and AMC, and consultation with experts	Ranking of the factors from the user and ridership analysis	Provide some policy guidelines for the improvement of BRTS ridership

1.6 Thesis Structure

The thesis contains 8 chapters as per the following sequence:

Chapter 1: Introduction- This chapter will present the research background, identify the research problem, and formulate possible objectives along with some specific research questions that can address the research problem.

Chapter 2: Literature Review- It will proceed to discuss relevant literature and try to explain the methods used in those literatures.

Chapter 3: Case Study of Ahmedabad BRTS- This chapter will give a short description of the study area itself including existing roadway network, phase-wise development of BRTS route.

Chapter 4: Data Collection: Approach and Methodology- This chapter will describe the methods of data collection like fixation of sample size and formulation of sampling strategy. Finally it will focus on specific methods for analyzing the collected data in order to obtain the research objective.

Chapter 5: User Survey Analysis - This is one of the main steps of this research where user analysis will be conducted based on the data collected through questionnaire survey at station level.

Chapter 6: Ridership Analysis -In this chapter, Ridership analysis will be conducted based on the data collected (spatial) on built form neighborhood attributes from all the BRTS stations.

Chapter 7: Policy Recommendation for BRTS Ridership- It will summarize the research findings and will provide some policy guidelines.

Chapter 8: Conclusion and Recommendation for Further Research: This chapter will provide conclusion as per specific objective and finally discuss on further scope of this research in future.

2 Literature Review

This chapter will provide a theoretical background on most used ridership indicators in relation to their applicability in a ridership model. More focus will also be made on the effective measure of each indicator.

2.1 Key Performance Indicators (KPI's) for Ridership Analysis

Ridership usually refers to the number of passengers per day using the transit services and is also expressed in other units such as passenger per vehicle kilometer, passenger per day per kilometer and so on. The performance indicators for ridership can be of two types- internal which is related with the service quality (comfort), pricing, operation characteristics (speed, frequency) of the system, and external which refers to the outside factors of the system along the transit corridor such as local economic condition, accessibility and so on. According to the Transit Cooperative Reseach Program (2007), external factors have potentially greater effect on ridership than internal factors. For instance, population density or local economic growth of the region have more influences on transit ridership than any internal service characteristics of transit like comfort, speed and so on. The formulated external factors are local and regional economy, integration of public transport with other modes and so on whereas the identified internal factors are service quality (frequency, passenger amenities), fare and pricing strategies and so on.

The Mineta Transportation Institute (2002) has described the most comprehensive external and internal factors that have impacts on transit ridership. The framework of that study is illustrated as follows in Figure 2-1.

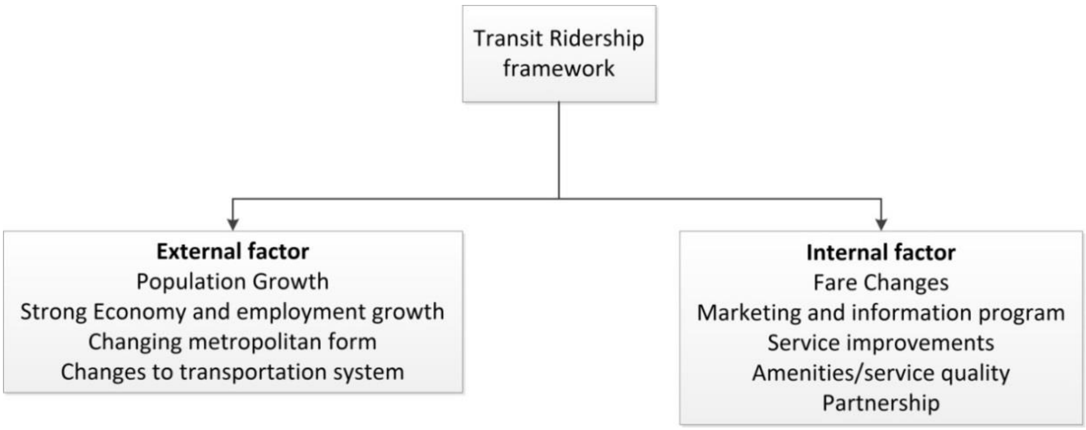

Figure 2-1: Framework of Transit Ridership

Source: (Mineta Transportation Institute, 2002)

The common framework found in the literature of BRT ridership is based on the study by Cervero, Murakami, & Miller (2010), illustrated in the following Figure 2-2.

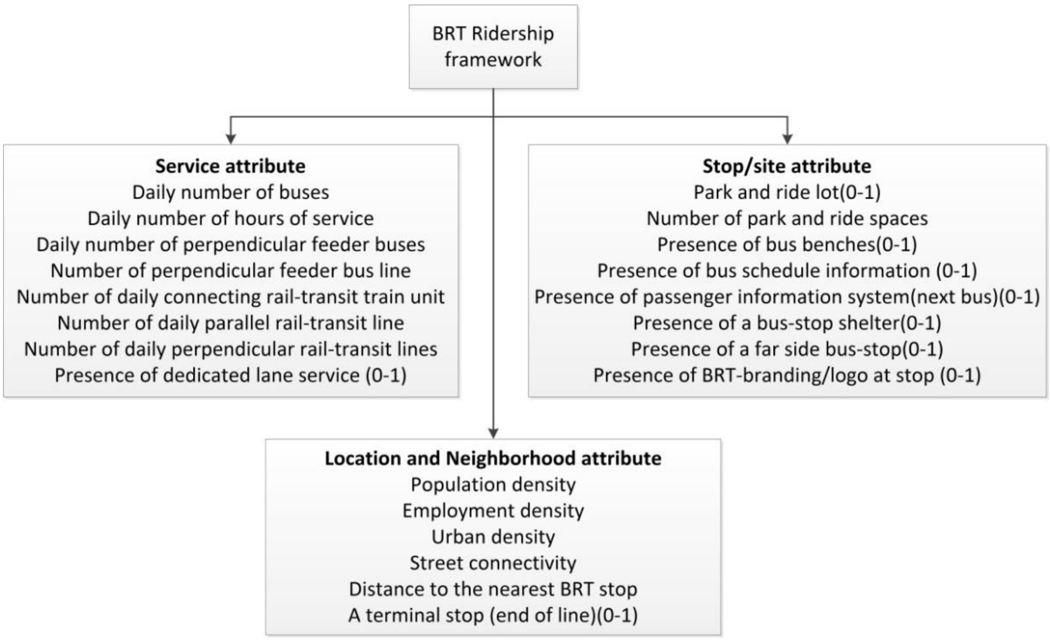

Figure 2-2: Framework of BRT ridership

Source-(Cervero et al., 2010)

It seems that both studies have used similar kinds of factor. External factors such as population growth, employment growth from the transit ridership framework were also used for the BRT framework under the location and neighborhood attribute. Besides, some new factors were introduced under the location and neighborhood attribute such as street connectivity, distance to nearest stop, terminal stop and so on which can also be termed as external factors of BRT. However, the service attribute and stop/site attribute of the BRT ridership framework can be fully represented by the internal factor of the transit ridership framework. Internal factors such as service improvement and amenities/service quality cover most of the factors under the service attribute and stop/site attribute of the BRT ridership framework.

In the previous framework, a general BRT ridership framework has been portrayed with three distinct attributes. Now more indicators will be explored to have insights on relevant indicators of ridership that have influence on ridership performance. Two groups of indicators can be identified to be discussed further, one is built-form indicator and another one is socio-economic indicator.

2.1.1 Built Form Indicator (BF indicator)

In the context of this study, the understanding of built form as a physical concept and its relationship with transit ridership is required. To develop this understanding, built form indicators will be defined and their relation with transit ridership will be discussed. The built-form indicators that will be discussed here along with specific measures are somewhat similar with the location and neighborhood attributes proposed by Cervero et al., (2010).

The conventional four step transportation model which was developed in the 1950's later included the built form indicator in the modeling process to analyze the relationship between travel behavior and built form indicator (Ma & Chen, 2013). At first, Stopher (1992) and Peng, Dueker, Strathman, & Hopper (1997) modeled transit demand and supply where they included some neighborhood variables such as land use mix, population and employment density. They have found that the relationship between demand and supply is quite significant and concluded that ridership depends partly on land use mix and density. The original built form indicators “3Ds” which were developed by Cervero & Kockelman (1997) are density, diversity, and design. Later it was added with two new indicators - ‘distance to transit stop’ and ‘destination accessibility’- in the research paper by Ewing & Cervero (2001). These five indicators make up the commonly used 5D indicators and each of them will be described in detail as follows.

2.1.1.1 Density

Density usually refers to the number of homes, people or jobs and so on per unit of area (Campoli & MacLean, 2002; Kuzmyak & Pratt, 2003). The effects of density on travel demand have long been recognized and remain used in travel behavior study. Higher densities are associated with more transit use, less car use with emphasizing on walking and cycling because public transit can be well operational in high density areas rather than car (Cervero & Kockelman, 1997; Kitamura, Mokhtarian, & Laidet, 1997; Schwanen, Dieleman, & Dijst, 2004; Stead, 2001). Besides, increase in density tends to reduce the travel distances to destinations thus promoting alternative mode use rather than car (Boarnet & Handy, 2010; Ewing & Cervero, 2010). Moreover, Levinson & Kumar (1997) have concluded that both travel time and trip distances tend to reduce along with the increase of land use density.

However, it has already been established that there is a positive relationship between population density and transit ridership at the station level (Parsons Brinckerhoff Quade & Douglas Inc., 1996) because it is more likely for the residents living close to the station to be travelling by the transit (Cervero, 1993) . Parsons Brinckerhoff Quade & Douglas Inc. (1996) has also found that ridership increases exponentially with the increase of employment along the transit corridor. Munshi (2013) has also observed that concentration of growth along the corridor tends to increase the transit ridership by reducing the travel distance for the commuters from their origin to transit stop. Short distance usually encourages the commuters to walk or use non-motorized modes to access to the stop.

Popular measures of density are population density, household density, residential density, job density, commercial and service density and so on (Munshi, 2013). Since workers are the everyday users, employment density is considered as most prominent indicator than other density for transit ridership.

Density is usually measured in per unit of area.

$$\text{Residential density, } D_r = \frac{P}{A}$$

$$\text{Employment density, } D_e = \frac{J}{A}$$

Where P and J refer to the total number of population and jobs respectively and A refers to an area measured in acre.

2.1.1.2 Diversity

A substantial body of researchers has agreed that mixed land uses (heterogeneity) have positive impact on travel behavior of commuters (e.g., Ma & Chen, 2013). Spears, Boarnet, & Handy (2010) have found that the elasticity of vehicle miles travelled (VMT) with respect to land use mix is negative which indicates an increase in land use diversity will significantly reduce the travel distance. Besides, the reduction of travel distance, significant increase in walking is also evident (Ewing & Cervero, 2010). Moreover, mix land uses make the walking and biking safe and convenient (Litman & Steele, 2012). In addition, Gao, Mokhtarian, & Johnston (2008) have demonstrated that residential areas with higher job accessibility are likely to own less cars and increase the use of transit which is also consistent with the study output by Kitamura et al. (1997). In general, a higher mixing of compatible land uses increases the opportunities for the commuters to access different associated functions within a short distance. Simultaneously, commuters find it easier to access to transit stop due to the higher integration of compatible land-uses around the stop. A proper mix of land-use also helps to generate new transit demand (Frank & Pivo, 1994).

Land-use diversity measures the degree of proximity among different land uses e.g. residential, commercial, industrial and so on. According to Boarnet (2011) ,entropy index is the most commonly used index for land use mixture. It quantifies the heterogeneity of land within a given area of interest. The original formula was developed by Frank & Pivo (1994) which was later simplified. The computation is quite simple for entropy as it takes vector data as input. The resulting value of entropy index is between 0 and 1, where 0 represents total homogeneity of land and 1 represents the highest variability of land (total heterogeneity). The expression of entropy index is as follows-

$$\text{Entropy index} = -\sum_j P_j * \ln(p_j) \, / \, \ln(J)$$

where: P_j = Proportion of land-use category j within a specified radius (service area) of the developed area; J= number of land-use categories.

However, the measure of entropy index is limited within a neighborhood area, typically having a buffer zone ranges from quarter to half mile (Cervero & Kockelman, 1997). So it may not be suitable for a neighborhood more than half mile radius. Recognizing the limitation of entropy index, Cervero & Kockelman (1997) developed a new diversity index which is not restricted by the size of neighborhood and relatively better measure for diversity. It calculates the land use mixture using many grid cells following the 8 cell neighborhood rule where the corresponding interaction of land-uses with one another is considered (see Figure 2-3). Likewise entropy index, dissimilarity index ranges from 0 to 1. The only difference is that it works on raster data format. According to Cervero & Kockelman (1997) dissimilarity index provides more accurate information of land use mixture rather than entropy because entropy index is unable to identify sprawling pattern of land.

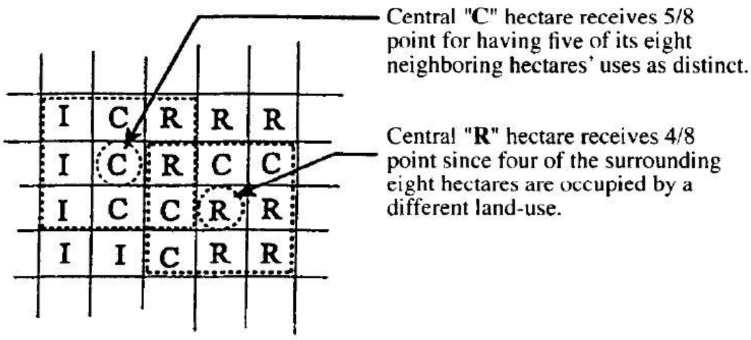

Figure 2-3: Computation of dissimilarity index

$$\text{Dissimilarity index} = \{[\sum_{j}^{k} \sum_{l}^{8} (\frac{X_l}{8})]/K\}$$

where K = number of actively developed hectare grid-cells, and X_l = l if land-use category of neighboring (immediate contact) hectare grid-cell differs from hectare grid-cell j (0 otherwise).

On the other hand, job-housing ratio only computes the number of jobs with respect to its housing in a neighborhood. Higher job-housing ratio tends to minimize the average commute distance for the workers in a neighborhood (Kuzmyak & Pratt, 2003; Weitz, 2003).

Another relevant measure, the Herfindahl index (HHI) is mostly used in economic analysis being expressed by the sum of squares of the proportion of different land use components. This is more similar with entropy index when standardized but was found insignificant statistically by Ritsema Van Eck & Koomen (2008). Besides, different metrics are available to quantify the land use composition such as Shannon's index (richness of diversity) and Simpson's index (evenness of diversity). They are mainly found in environment literature and are used to measure species (both flora and fauna) biodiversity but have limited use in transportation (Colwell, 2009; Nagendra, 2002).

2.1.1.3 Design

The concept of design has originated from the idea of standard suburban neighborhood design which is characterized as site design, dwelling and street characteristics with small block size, a complete sidewalk system, absence of cul-de-sac and limited residential parking which ultimately encourage walking and cycling (Cervero & Kockelman, 1997; Gorham, 2002; Hess, Moudon, Snyder, & Stanilov, 1999; Mcnally & Kulkarni, 1997; Stead, 2001). However, in the 5D concept it is specified to only road design or road connectivity. Road Connectivity refers to the degree to which a road is connected towards destinations. A poorly connected road network with many cul-de-sacs (dead end) diminishes accessibility to destination and increases the commuting distance. On the other hand, increased connectivity reduces travel distance which enhances the walking environment (Litman & Steele, 2012).

Connectivity can be measured using various indices, including road density, intersection density, proportion of four-way intersections, and proportion of dead-end streets (Dill, 2005; Handy, Paterson, & Butler, 2004) . Ewing & Cervero (2010) have emphasized on the measure of street connectivity and intersection density. They have concluded that increasing intersection or street density reduces vehicle miles travel (VMT) by 1.2%.

There are also some popular measures for road connectivity like Beta index and Gamma index as extracted from the graph theory by Rodrigue & Comtois (2006). The beta index is similar in operation with street connectivity index as proposed by Ewing & Cervero (2010).

$$\beta = \frac{e}{v}$$

$$\gamma = \frac{e}{3(v-2)}$$

Where, *e* and *v* refer to the edges (link) and vertex (node) respectively.

On the other hand, intersection density is determined using the road network taking into account the true intersection (three or more legs) (Cervero et al., 2010).

Intersection density = number of true intersections / km^2 of land area

2.1.1.4 Accessibility

Accessibility, a concept used in a number of scientific fields such as urban planning, transport planning and so on, refers to the ability and ease of people to overcome the friction of distance in order to participate in different activities (Geurs & van Wee, 2004). It was first introduced by Hansen (1959), where he termed the activities as potential opportunities that can be reached within a certain time or distance threshold. In terms of geographical scale, accessibility varies within two types- regional accessibility and local accessibility- where regional accessibility refers to the accessibility level from one region to another region while local accessibility only considers the accessibility in the region itself (Ewing, 1995; Kuzmyak & Pratt, 2003).

Ewing & Cervero (2010) and Kockelman (1997) concluded from their study that good accessibility at the regional scale has significantly reduced the travel time of the commuters to obtain the same opportunity. Besides, it has shifted the user to transit from automobile use.

Geurs & van Wee (2004) identified four measures of accessibility which are infrastructure-based, location-based, person-based and utility-based measures. Among these four types, location-based measure is the most used measure for the estimation of accessibility. In relation to location based measure, two approaches are commonly used to measure accessibility: contour-based measure and gravity-based measure.

Contour-based measure is used to identify the number of opportunities within a given distance threshold. It is a popular measure to compare the accessibility of different modes using the same distance or time threshold and similarly useful to identify the accessibility for a specific mode using multiple distance threshold. Although it has simplicity to interpret and communicate, it has several weaknesses. Firstly it is unable to take into account the competition effects among the opportunities in the specified distance threshold which make it obsolete to measure land use and transport changes over time (Geurs & Ritsema van Eck, 2001), secondly, the measure does not consider the perceptions and preference of the commuters for any opportunity which can be explained by the utility based measure.

On the other hand, gravity-based measures overcome most of the limitations of contour-based measures. It includes all possible destinations considering the distance decay function which is analogous to Newton’s law of gravitation: the weight of each opportunity is inversely proportional to the square of the travel time (distance) required to reach that opportunity (Owens & Levinson, 2012). Most researchers suggest that a negative exponential weighting function is a more accurate representation which is more substantial to present the outcome. However, choosing the appropriate weighting function and coefficients add complexity to this measure which makes the resulting outcome difficult to interpret. The equations for each of the two cited location-based measures are as follows:

Contour (Isochronic) based measure:

$$AI_i = \sum_j [jobs_j(time \leq m)]$$

Gravity base measure:

$$AI_i = \sum_j [jobs_j * e^{(-v\, time_{ij})}]$$

m = time threshold (e.g., 30 minutes)
Jobs = Number of jobs in tract
Time = network travel times
i = residential zone
j = employment zone (Cervero, 2005)

2.1.1.5 Distance to Transit Stop

"Distance to transit stop is usually measured as an average of the shortest street route from the residences to the nearest stop in an area" (Ewing & Cervero, 2010). Alternatively, it is defined as the access and egress distance an individual has to travel to access transit stop and destination respectively. The longer the distance an individual has to walk or travel to or from transit stop, the lower the chance of using specific service (Munshi, 2013).

The most used measure is distance between transit stops. Another prominent variable used is population living within walking distance of a transit stop (Munshi, 2013). Alternatively it can be measured as transit route density, or the number of stations per unit of area.

2.1.2 Socio-Economic Indicators

In addition to the built-form indicators, socio-economic indicators are thought to have significant influence on travel behavior and thus on ridership. According to Ewing & Cervero (2001) built form has a greater impact on trip length but not in mode choices. They have further concluded that choice of mode is primarily a function of socio-economic characteristics of commuters. Thill & Kim (2005) have also believed that travel behaviors are more likely to be affected by socio-economic characteristics such as automobile ownership, income, employment status and so on. However, Ashalatha, Manju, & Zacharia, (2013) have found that with the decrease of income, people start to shift to transit use and this outcome is also consistent with the result from Liu, (2007) and Nurdeen, Rahmat, & Ismail (2007).

2.2 Literatures on Ridership Model

In this section, literature on ridership model will be explored, specifically those that have included the built form indicators (5D), socio-economic indicators. Consequently it will be possible to identify how researchers have fitted the indicators in a ridership model and interpreted the model accordingly.

2.2.1 Ridership Models

Numerous studies have been found on ridership but very few considered the built form indicators as explanatory variables. Two reasons can be identified behind this - firstly, it's a somewhat new idea which was first published in 2001 (Ewing & Cervero, 2001). Secondly, most of the studies have compared the ridership performance based on service and station characteristics among BRT systems across different cities or countries where the use of built form indicators may not be significant enough at a city or country scale (Hensher & Golob, 2008; Hensher, Li, & Mulley, 2014). Few studies have included some of the built form indicators that are found to be significant with ridership. Those studies are outlined as follows in Table 2-1.

Table 2-1: Ridership studies showing the BF indicators

Study source	Dependent variable (unit)	Independent variable		Sample size
		Built-form variable	Qualitative variable (Dummy)	
(Estupiñán & Rodríguez, 2008)	Daily boarding per station	Land use index, density, road density, sum of intersection and so on.	Station characteristics and Perception about safety, clean, pedestrian friendly, bike friendly as extracted from the user	68 stations of Bogota BRT
(Kuby, Barranda, & Upchurch, 2004)	Average weekday boarding	Number of Employment and population within walking distance, station spacing	Some station and city wise dummy variable	268 station in USA
(Cervero et al., 2010)	Average daily boarding	Population density, distance to nearest BRT stop	Some service and station dummy attributes	69 BRT stop of Los Angeles BRT
Chu (2004)	Boarding	land use mixture, accessibility, pedestrian environment	Interaction with other mode	2000 stops in Florida
(Currie & Delbosc, 2013)	Boardings/ Veh-Km (BVK)	Residential Density Employment Density Stop Spacing % Accessible % Segregated Right-of-Way	Integrated Fares , Capacity (category)	101 (BRT, LRT and SC)

In most of the studies of ridership, multiple regression method was performed because of its capability of dealing with a large number of factors. It has the ability to deal with numerical variables and binary (dummy) variables, and in several conditions, it is required to use the categorical variable for evaluations due to unavailability of absolute data (Kuby et al., 2004).

In a regression equation, a set of potential drivers of ridership are identified from the associated coefficient values. The coefficients are meant to explain the significant influence of explanatory (independent) variables on the dependent variable (ridership) (Hensher &

Golob, 2008; Hensher et al., 2014). In Hensher & Golob (2008), Ordinary Least Square (OLS) regression was used to investigate the potential drivers of BRT ridership. A key assumption of OLS regression is that all explanatory variables need to be independent. The simple form of OLS regression equation is as follows.

$$Y_i = \beta_0 + \beta_i X_i + \epsilon_i$$

Where Y_i refers to the dependent variable, X_i to the independent variable, β_0 is a constant and β_1 is the coefficient to be estimated, and ϵ_i is the error term.

2.2.2 Transit Mode Choice Model

Mode choice analysis has significant influence in transit planning. It plays a key role in finding out the factors that motivate commuters to choose a specific mode (Abdulsalam, Miskeen, & Alhodairi, 2014). Moreover, mode choice study helps to assess the existing transit system performance. Commuter mode choice is generally explained by three factors: trip characteristics, socio-economic characteristics of the commuter, and the transport system (Arasan, Rengaraju, & Rao., 1996). Relevant studies of mode choice analysis have also concluded that the choice of mode varies with socio-economic and travel characteristics of the commuters. Mahlawat, Rayan, Kuchangi, & Patil (2007) and Nurdeen et al. (2007) have found that factors such as travel time, travel cost, age, gender and car ownership are significantly influencing the mode choice, and moreover, travel time and travel cost have emerged to be the most prominent elements for attracting car users towards public transit.

The general concept of mode choice model is that passenger will maximize their utility by choosing the mode based on the attributes such as fare, travel time, frequency and so on. Mode choice model generally has two categories- aggregate discrete choice model and disaggregate discrete choice model. The basic difference of the two choice model is that aggregate model predicts considering the collective behavior of commuters such as car ownership rate per unit of area, average income per unit of area whereas disaggregate model considers the mode choice at individual or household level (Ashalatha et al., 2013). Disaggregate models can provide accurate estimates for transit demand considering the socio-economic and trip characteristics. However, extensive data is required for disaggregate model to analyze the mode choice which is usually gathered from field level sample survey (Koppelman & Bhat, 2006).

The most widely used models of mode choice analysis are binary logit model (between two modes) and multinomial logit model (more than 2 modes) (Arasan et al., 1996; Ghareib, 1996; Mintesnot & Takano, 2005; Yamamoto, Fujii, Kitamura, & Yoshida., 2000). Logit is widely accepted model from the analytical point of view rather than Probit. Logit is developed on simple mathematical form and easy for estimation and calculation and has the ability to add or remove choice alternatives (modes). The probability of choosing a mode from a set of alternative modes is a function of the utility of modes calibrated from the selected attributes (Ashalatha et al., 2013).

The expression for the probability of choosing an alternative i from a set of j alternatives is as follows:

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

where $P_r(i) =$ probability of choosing alternative i; V_j = utility of alternative j.

The utility for mode *i* derived from a linear function of the explanatory variables is as follows:

$$V_i = \beta_0 + \beta_1 X_1 + \cdots + \beta_n X_n$$

Where $Vi =$ utility function for mode i

$\beta_1, \ldots .., \beta_n$ are the coefficients associated with explanatory variables

$X_1, X_2, \ldots \ldots .., X_n$ are the explanatory variables for mode i

So far, different ridership indicators and their associated measures have been explained which will help the researcher to develop an appropriate methodology for the study. Prior to that, a general overview will be portrayed on the case study followed by the detailed approach of data collection and methodology.

3 Case Study of Ahmedabad BRTS

Ahmedabad is one of the blooming cities in India, which has been an important industrial center of India. Ahmedabad accounts for 7% of the state's (Gujarat) total population and around 20% of total urban population. It contributes to 17% of the state income (GIDB, 2005). In addition, Ahmedabad is the home of several scientific and educational institutions with national, regional and global importance. The western part of the city has developed as a mainly high income residential area and major institutional area whereas the eastern part has the major industrial estates. Because of this, the traffic flow is very heavy from west to east in the morning and vice-versa in the evening which causes serious traffic congestion in the morning and evening peak periods. Consequently, the air pollution has become severe (Khanna, 2009).

Figure 3-1: Location of Ahmedabad in India

Source: (Shastry, 2010)

The trans-vision of Ahmedabad in City Development Plan was declared as 'accessible Ahmedabad' aiming to redesign the city structure and transport systems towards greater accessibility, efficient mobility and lower carbon future. The vision aims at reducing need for travel, reducing the length of travel and promoting the use of public transport and NMV, and reducing automobile dependence. Introduction of Bus Rapid Transit system is one of the components of this vision, which was proposed as a viable option. (Ahmedabad Municipal Corporation, n.d.).

The city transportation system is predominantly dependent on roadway systems. The city road network is composed of 5 ring roads and 17 radial roads. AMTS (Ahmedabad Municipal Transport Service), a municipal body, has been providing transport services since 1947, and started with a fleet size of 112 buses. Today, AMTS operates on a fleet size of 1152 along 173 routes. Daily boarding has reached 0.8 million passengers. However, the service has deteriorated significantly over the years and has also faced a substantial decline in its ridership, due to a lack of route rationalization and an inability to upgrade the infrastructural base to cater for the growing demand. This consequence has led to a sharp increase of two-wheelers ownership (Ghelani, 2014).

For BRTS implementation, a number of aspects have been considered in a successful way. The most important was to develop a citywide transport plan which will integrate not only with the current land-use plan but also take into account the future development plan of the city. BRTS was also aiming to be connected to some of the entry points of different gateways to serve the commuters citywide as Ahmedabad city is well connected by an expressway, several national and state highways, the broad gauge and meter gauge railways (Ahmedabad Municipal Corporation, n.d.).

As mentioned earlier, Janmarg BRTS was developed in 2 phases. The first phase of the project covered 58 km whereas in phase 2, attempts were made to complement the phase 1 by making more areas accessible. The outlying suburbs which were developing rapidly were also connected by BRTS network. Development of corridors in 2 phases is outlined in the following Table 3-1and Figure 3-2.

Table 3-1: Development of corridors in two phases

Phase I		**Phase II**	
Corridors	**Length (km)**	**Corridors**	**Length (km)**
RTO-Pirana	12.5	RTO-Sabarmati-Chandkheda	6.6
Narol-Naroda	13.5	AEC junction-SG highway (Sola)	3.10
Pirana-Maninagar-Narol	12	Shivranjini-Iskcon-Bopal	6.5
Shah Alam-Soni ni chali	7	Nehrunagar-Gujarat College-Geeta mandir	6.2
Bhavsar hostel-Prem Darwaza	8	Soni ni Chawl-Odhav	3.5
Naroda-Kalupur	5.3	Dariapur Darwaza-Kalupur-Sarangpur (Elevated corridor)	4.5
Total	**58.3**		**30.5**

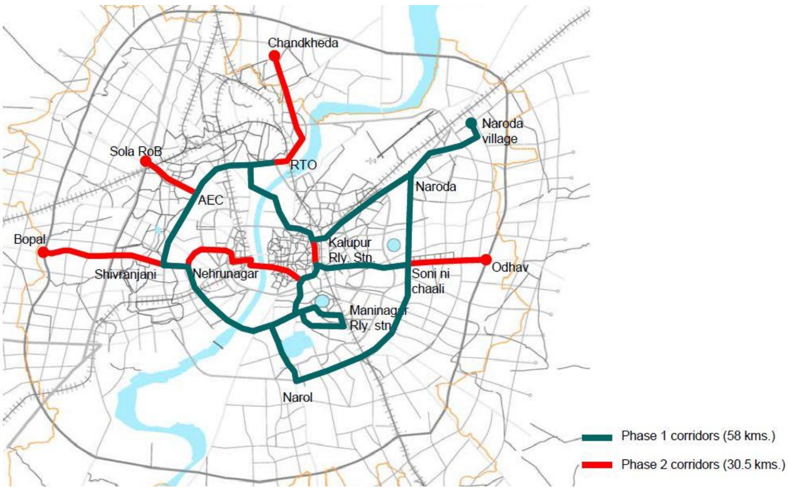

Figure 3-2: Map showing the corridors of two phases

Source: (Ahmedabad Municipal Corporation, 2008a)

Twelve BRT trunk routes have been identified, which were structured in an integrated way to operate the transit services. Following Figure 3-3 shows the major 12 BRT trunk routes along with their stations.

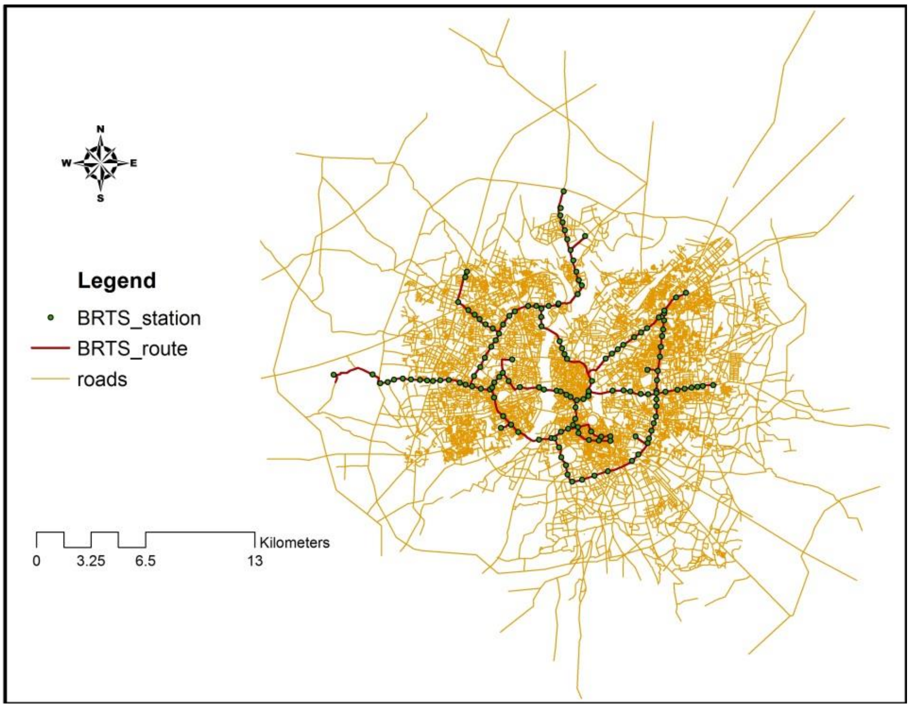

Figure 3-3: Map showing the 12 BRT trunk routes

4 Data Collection: Approach and Methodology

For this study, an empirical fieldwork was carried out during 3 weeks, starting from 27th September to 19th October, 2015. The primary data collection, a user survey was developed by following a structured questionnaire format. It was conducted in BRTS stations, while some AMTS stations were chosen along with the same route of BRTS in order to conduct the AMTS user survey assuming that AMTS users are the potential users for BRTS if they could be shifted to BRTS by applying any possible measure. The secondary data was gathered from 4 sources: Ahmedabad Janmarg Limited, a statutory body (operation) of Janmarg BRTS; Ahmedabad Municipal Corporation; Centre for Urban Equity (CUE) and CEPT University. Some available online resources from the website of Ahmedabad Urban Development Authority (AUDA) and Gujarat Infrastructure Development Board (GIDB) were also used.

4.1 Collection of Primary Data

The user questionnaire survey was carried out to identify the socio-economic characteristics and trip characteristics of the commuters. The commuters were also asked about the reasons behind using a specific service (BRTS and AMTS) and suggestions for the service improvement. The resulting outcome will help the researcher to make a comparative study between these two modes.

4.1.1 Survey Area Selection

The stations were selected with the purpose of collecting information from each route. A total of 18 stations were chosen from BRTS relating to university station, major transfer station, and economic zone station while 13 stations from AMTS along the same route of BRTS. Since AMTS stations are not frequently spaced, it was not possible to take more stations within the given timeframe. The targeted respondent was a regular user over 16 years of age. Table 4-1 represents the total number of respondents taken from each selected station.

Table 4-1: Samples taken from each station

BRTS station	Number of respondents	AMTS station	Number of respondents
Sola Cross road	10	Motera (Visat)	6
Iskon Cross road	11	Kalupur	22
RTO Circle	10	Sarangpur	8
Anjali	10	Gitamandir	10
Kankaria Lake	10	Vijay Cross road	7
Shivranjani	10	Akhbarnagar	7
Visat	10	Vasna	8
Govt Litho Press	11	Naroda	7
Kalupur Railway Station	15	LD Engineering College	6
Sarangpur	9	Navarangpura	5
Memco Junction	10	Income Tax Office	11
Soni Ni Chali	12	Paldi	16
Thakkarnagar Approach	10	Lal Darwaja	27
Express Highway Junction	5		
Narol	9		
Town hall	10		
Gitamandir	12		
LD Engineering College	11		
Total	**185**		**140**

4.1.2 Survey Design

The questionnaire was divided into two parts. The first relates to information about Socio-economic factors: education level, household income, occupation, age, gender and ownership of private vehicles. The second part focuses on the travel behavior of the user. It includes questions about the purpose of trip, status of access and egress in terms of time and mode, frequency of trip and also the perception about the service attributes such as fare, speed, frequency, vehicle cleanliness, vehicle comfort, service reliability and safety/security. The questionnaire is appended in Appendix-I and Appendix-II.

4.1.3 Data Collection

To undertake the user survey, 4 surveyors have been employed. After training, a pilot survey was conducted at LD Engineering College station for both BRTS and AMTS users to test how people would respond to the questionnaire. Based on the pilot survey, necessary adjustments have been made to the questionnaire by changing the question sequence and wordings, adding more categories in some questions and so on. Two pages of guidelines were distributed among the surveyors explaining the origin, destination, boarding and alighting station, definition of service categories so that it would be easier for the surveyor to conduct the survey efficiently in a less possible time. It was advised to the surveyors to ask some sensitive questions like family income, education level at the end of survey because it could have disrupted the data collection from the user, some respondents might not feel comfortable with such questions.

Some instructions were given about the time of data collection, usually in peak hours in weekdays, in order to have an increased number of responses. All 4 surveyors distributed the nearby stations equally on region basis among them for data collection. Random visits to the survey stations were made in order to check the data collection process by surveyors as per given requirements and guidelines. However, after finishing the survey in each day, survey sheets were accumulated from the surveyors to check and verify the data. Sometimes, some mistakes were found like: not asking all the questions, forget to fill up the questionnaire properly and so on. Therefore, the surveyors were informed immediately about the mistakes made so that they wouldn't repeat the mistakes in the next day. Some questionnaires were discarded immediately which were not filled up properly and the new target of survey number was fixed accordingly.

4.1.4 Key Expert Interview from CUE, CEPT University

Before starting the user survey, a meeting was arranged with the Technical team of CUE who planned and designed the Janmarg BRTS, to have a general overview on the study area. They have provided suggestions on the choice of station for conducting the survey and guidelines on surveying potential users from AMTS which were helpful for an effective survey design. Moreover, they have provided assistance by arranging a Janmarg authorization letter, which was required to conduct the survey at the station level, and by giving some important latest information on BRTS such as cancellation of phase-3 BRTS route, number of total station including cabin station and so on.

In addition, an overall idea about the BRTS station characteristics such as location of park and ride (bike and ride), bicycle track, footpath, pedestrian access and flyover station have been gathered. Station characteristics might be helpful to develop the methodology for ridership. Existing route map, route width map were also provided by them.

4.1.5 Key Expert Interview from Ahmedabad Janmarg Limited

The operating authority of BRTS, Ahmedabad Janmarg Limited, has kept the right for reserving all sorts of information about BRTS operation. They update the service information in every 15 days. A meeting was also arranged with the Janmarg personnel to gather more information about the future plan of BRTS route extension, accessibility, status of integration of 'MYBYK' plan (bike share) with BRTS and so on. These information will be used to a large extent for the policy formulation of this study. In addition, monthly boarding and alighting data were also provided by them which will be used in a ridership model for prediction.

4.2 Collection of Secondary Data

In order to get an overview on the existing policy regarding Ahmedabad transportation system, Janmarg BRTS, City future plan and so on, several policy reports need to be discussed which will help the researcher to develop a policy guideline for the improvement of Janmarg BRTS in conformity with the existing policy.

In Detailed Project Report on phase-1 BRTS, the feasibility study on the introduction of BRTS was outlined along with a proper delineation of existing transportation system and a projection (population) of travel demand for the city of Ahmedabad. Therefore, it has proposed the BRTS as a viable option to meet the overgrowing demand. A total length of 58 km route has been proposed with necessary designs and illustrations. In phase-2 report, more rigorous study was done focusing on the implementation status of phase-1 and based on shortcomings in phase-1; necessary adjustments were made to integrate the both phases. In phase-2, a total length of 30.5 km route was added to make an effective, efficient and sustainable transport system for the city dwellers. In addition, in both report, it has stated its vision along with possible strategies to achieve the vision. In strategy, it has focused on to promote Transit Oriented Development (TOD) by intensifying land along the corridor to make the city compact. It has also emphasized on to promote non-motorized mobility with proper facility integration for bicycles and pedestrians (Ahmedabad Municipal Corporation, n.d.).

As already mentioned, BRTS is fully planned and designed by the technical support team of CEPT University. So a lot of resources available in the form of report, dissertations, articles at CEPT library which helped the researcher to gather more subsidiary information for this study.

4.3 Flowchart of Methodology

A brief methodological framework is outlined in the following Figure 4-1 and involves the steps of development of conceptual framework, data collection, data analysis and finally some policy guidelines for Janmarg BRTS.

In the 1st step, a thorough overview of literature was conducted in order to identify the commonly adopted framework used in BRT ridership studies. Therefore, the selected framework was grouped to expedite the consultation meeting with the local experts from CEPT, AMC who are aware enough about the relevant factors of specific Janmarg BRTS context. After having a fruitful consultation meeting with the experts, the final framework was documented to carry out the field work.

The 2nd step involves the data collection phase during fieldwork. Here, stop/stations were chosen as a sampling unit for the data collection. So, most of the data have been collected from the sampled stops. To obtain the socio-economic and trip characteristics data, user survey at both stations, BRTS and AMTS, has been conducted by using a structured questionnaire format. Some data was also gathered pertaining to stop attributes from the secondary sources such as archive of CEPT, AMC and AUDA. Quantitative data like ridership, population density, employment density, street connectivity factor and so on would not be possible to retrieve from primary sources. Hence, Ridership (number of boarding) have been collected from AJL (Ahmedabad Janmarg Limited) while neighborhood attributes data like population density, employment density, street connectivity and so on were extracted from previous researches of ITC on built form environment.

In the 3rd step, analysis applying a regression method will be conducted. All the survey data were encoded in a SPSS file immediately after collection. SPSS offers convenient methods both for data entry and data processing by developing a variable view and a data view. It’s also very handy for any statistical analysis and to export data in any other format required such as in MS Excel or R (Geo-statistical software). Two steps of regression analysis will be followed, one is to conduct a mode choice analysis by using the binary logistic method and the other one is the ridership analysis which will be facilitated by the multiple regression method.

Prior to the main analysis, data will be processed to check the correlation among the variables. After getting the calibrated result through the regression analysis, prediction accuracy (R^2) will be computed for both models. For the statistical analysis, SPSS software will be used to a greater extent and for delineation of maps, GIS software would be supportive (Dopheide & Martinez, 2015; Hensher & Golob, 2008).

The last step of this methodological framework is to provide some policy guidelines for the improvement of Janmarg BRTS based on the results and findings from the analysis. The proposed policy guideline will be in conformity with the existing policies.

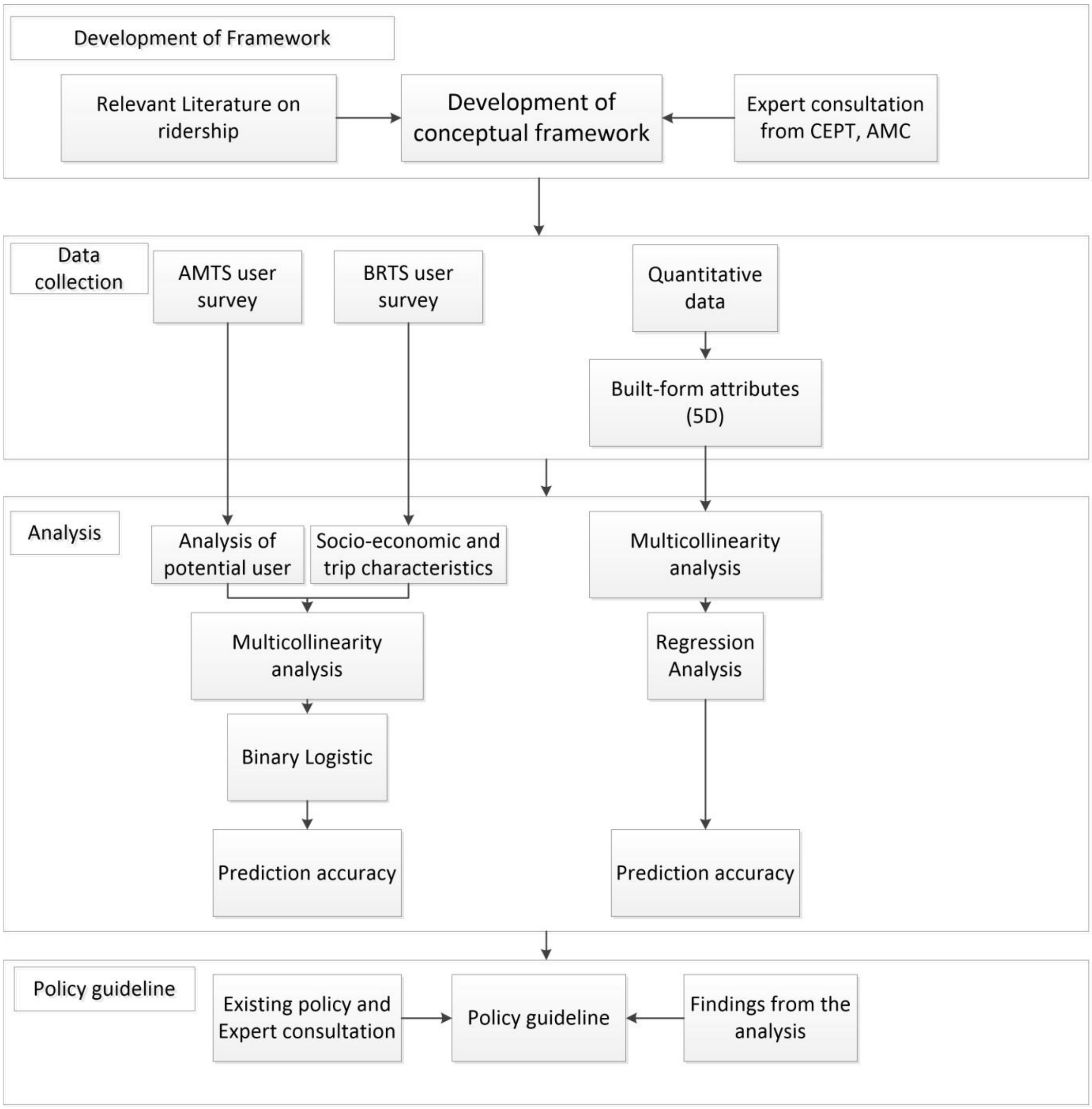

Figure 4-1: Methodological steps of the research

5 User Survey Analysis

5.1 BRTS User Analysis

There is a close relationship between socio-economic characteristics and the mobility patterns of people. This implies that socio-economic profile dictates the travel behavior of people. Both mobility and socio-economic profile have influence on the trip purposes and characteristics (Bajracharya, 2008). Therefore, in the next two sections, the collected data for users of BRTS will be analyzed descriptively, in relation to their socio-economic and trip characteristics.

5.1.1 Socio-Economic Characteristics

Socio-economic characteristics play an important role on the travel behavior of people. Therefore, those characteristics are important determinants for choosing specific transport service. From the total BRTS responses, the majority of the BRTS respondents are males (58.7%). Their main occupation is 'business or private service' (51.6%), followed by students (15.8%). As per age, 44.6% individuals belong to the category of 25-45 years of age.

The economic status of the population within the AMC jurisdiction is defined by the Gujarat Housing Board. In Gujarat, the income classes have been categorized into economically weaker section (EWS), lower income group (LIG), middle income group (MIG) and higher income group (HIG) with threshold of income up to Rs. 8,333, between Rs. 8,333 and Rs. 20,833, between Rs. 20,833 and Rs. 41,666 and above Rs. 41,666 respectively. The survey reveals that, 93.5% people answered the question about their family income. From Table 5-1, it is prominent that most of the users belong to the middle income group (36.4%) and higher income group (30.4%). This gives an indication that middle and higher income group can afford this service than lower income group. Table 5-1 contains the analysis of the socio-economic characteristics of BRTS respondent.

Table 5-1: Socio-economic characteristics of BRTS respondents

Parameters	Absolute values	Relative Values (%)
Total Observation	184	
Sex		
Female	108	40.8
Male	75	58.7
Missing	1	0.5
Age		
Under 25	36	19.6
25-45	82	**44.6**
45-65	52	28.3
Above 65	11	6.0
Missing	3	1.6
Occupation		
Student	29	**15.8**
Business/Private service	95	**51.6**
Government Service	20	10.9
Retired	2	1.1

Parameters	Absolute values	Relative Values (%)
Self employed	17	9.2
House wife	20	10.9
Missing	1	0.5
Family Income		
Upto Rs. 8,333 (EWS)	5	2.7
Rs. 8,333-20,833 (LIG)	44	23.9
Rs. 20,833-41,666 (MIG)	67	**36.4**
Above Rs. 41,666 (HIG)	56	**30.4**
Missing	12	6.5

In terms of vehicle ownership, out of total BRTS respondents only 24% people have their own car, while motor scooter is owned by most of them, about 70%. See Table 5-2 for further details-

Table 5-2: Vehicle ownership of the BRTS Respondents

Parameters	Absolute values	Relative Values (%)
Total Observation	184	
Car Ownership		
Yes	45	24.5
No	135	73.4
Missing	4	2.2
Motor Scooter ownership		
Yes	129	**70.1**
No	52	28.3
Missing	3	1.6

5.1.2 Trip Characteristics

In this section, trip characteristics of the BRTS users will be analyzed. Here the focus will be on trip frequency, trip purpose, status of access and egress in terms of time and mode and peoples' perception about the services.

Table 5-3 shows that BRTS is mostly able to attract the daily user i.e. working class and students. Out of the total trips, almost 63% trips are made daily (6 days in a week). Those trips are mainly made for participating in work and school activities.

Table 5-3: Crosstab between trip purpose and trip frequency

Trip Purpose	**Trip Frequency**						
		Everyday	5 days in a week	4 days in a week	3 days in a week	Others	Total
	Work	43.20%	2.60%	2.60%	3.20%	5.80%	**57.40%**
	School	17.40%	0.00%	0.00%	0.00%	1.30%	**18.70%**
	Recreation	0.60%	0.60%	0.00%	2.60%	11.00%	14.80%
	Shopping	0.60%	0.00%	1.90%	1.30%	1.30%	5.20%
	Others	0.60%	0.00%	0.00%	1.30%	1.90%	3.90%
	Total	**62.60%**	3.20%	4.50%	8.40%	21.30%	100.00%

Access and egress are the main determinants for creating any trip by BRTS. If accessibility to boarding stop or to destination is hampered due to time delay or availability of a mode, people are not willing to use a specific service, in particular BRTS service. From the Table 5-4, almost 65% respondents walk to their boarding stop which approximately takes less than 10 minutes. Respondents using other mode as an access mode are very few; in total 28% respondents use motor scooter and auto-rickshaw as their access mode where auto-rickshaw is dominant (20.7%). Overall, it reveals that BRTS is not able to attract the people from longer distances; only people living within 10 minutes walking distance are the main source of ridership for BRTS. The same statistics is also true for egress mode. Access to destination by walking within 10 minutes was mentioned by 64% respondents. Motor scooter and auto-rickshaw were reported to have a share of total 28% as an egress mode. See Table 5-4 and Table 5-5 for more details-

Table 5-4: Crosstab between access mode and access time

		Access time					
		<5 minutes	5-10 minutes	10-20 minutes	20-30 minutes	> 30 minutes	Total
Access_mode	Walking	35.30%	29.30%	6.00%	0.00%	0.00%	**70.70%**
	Motor Scooter	1.60%	3.80%	1.60%	0.00%	0.00%	7.10%
	Auto-rickshaw	1.60%	7.10%	8.20%	2.20%	1.60%	**20.70%**
	Others	0.00%	0.00%	0.50%	0.50%	0.50%	1.60%
	Total	38.60%	40.20%	16.30%	2.70%	2.20%	100.00%

Table 5-5: Crosstab between egress mode and egress time

		Egress time					
		<5 minutes	5-10 minutes	10-20 minutes	20-30 minutes	> 30 minutes	Total
Egress_mode	Walking	39.30%	24.70%	4.50%	0.60%	1.10%	**70.20%**
	Cycle	0.00%	0.60%	0.00%	0.00%	0.00%	0.60%
	Motor Scooter	0.00%	3.40%	0.60%	0.60%	0.00%	4.50%
	Auto-rickshaw	1.10%	3.90%	14.60%	3.90%	0.00%	**23.60%**
	Others	0.00%	0.00%	0.60%	0.00%	0.60%	1.10%
	Total	40.40%	32.60%	20.20%	5.10%	1.70%	100.00%

In order to get insights about the perception of users towards the services of BRTS, respondents were asked to indicate all the service attributes from a list of attributes that have influence on the choice of BRTS mode. Respondents are in general satisfied with most of the services. More than 50% respondents pointed out the vehicle comfort, vehicle cleanliness, speed and frequency of BRTS which are attracting them to use this service. Around 44% and

38.6 % respondents indicated about the accessibility to station and to destination respectively as one of the reasons for choosing this service. So accessibility is one of the main factors for choosing the BRTS as a main mode. See Figure 5-1 for more details-

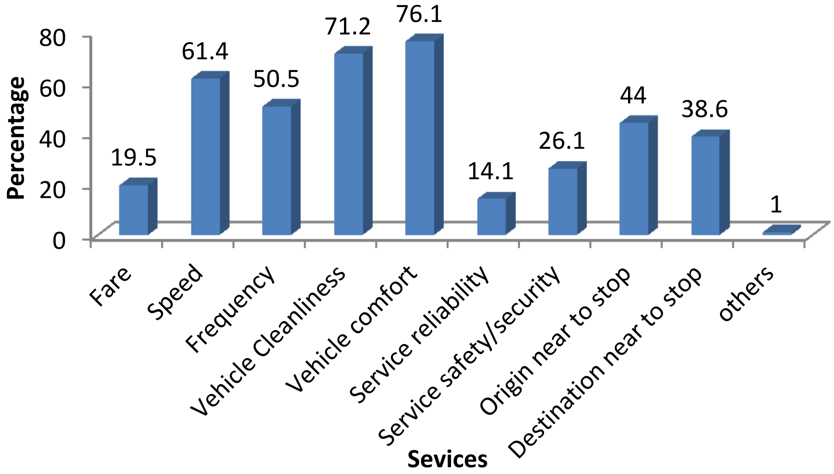

Figure 5-1: User perception about the service attributes of BRTS

In addition, respondents were asked to give suggestions to improve the services. Around 37.4% respondents emphasized on the fare reduction, whereas service reliability (on time service) at peak hours was mentioned by 25.5% of the respondents. By increasing the frequency of buses, waiting time at station can be reduced and on-time services can be ensured, that's why 19.5% of the respondents mentioned about the increase of frequency at peak hours. About fare, 17.9% indicated that they would appreciate the introduction of a day pass and monthly pass at a subsidized rate. As most of the users are frequently using this service (see Table 5-3), this pass system will probably be more affordable to them. Besides, 9.2% of the respondents mentioned to install CCTV camera inside the BRTS bus to avoid pick-pocketing and theft. Some respondents also emphasized on introducing water and sanitation at the station. Respondents also pointed on the development of new route because they only use this service when its service area (route) is near to their origin and destination. Almost 12% of the respondents pointed out about different services for improvement which are aggregated in 'Others'. The major services under this category are: proper announcement of destination (automatic device) in bus, available information on upcoming bus in platform, more ticket booths in prominent stations, minimize intersection delay, quick delivery of smart card and so on. See Table 5-6 for further details-

Table 5-6: Suggestions to improve the services of BRTS

Service attributes	Frequency	%
Fare reduction	55	**37.4**
Speed	7	3.8
Frequency	36	**19.5**
Vehicle comfort	3	1.6
Service reliability	47	**25.5**

Service attributes	Frequency	%
Service safety/ Security	17	**9.2**
Water and sanitation	15	**8.1**
Separate seat for ladies/Senior citizen	8	4.3
Direct bus	12	6.5
Development of new route	15	**8.1**
AC bus	2	1
Introduce Monthly pass/Day pass	33	**17.9**
Others	22	**11.9**

5.2 AMTS User Analysis

AMTS users are assumed to be the potential users for BRTS. As such AMTS users along the same route of BRTS were also surveyed. In this section, the main focus will be given only on the socio-economic profiles of the AMTS users and their perception towards the services of AMTS. In the next section, trip characteristics of AMTS users in comparison with BRTS users will be explored.

5.2.1 Socio-Economic Characteristics

From the total AMTS responses, majority of the respondents are male (53.6%). Among the AMTS riders, highest 39.3% of the respondents are doing business or private service, followed by students (20%). On the other hand, as per age, 34.3% individuals belong to the category of 45-65 years of age.

In terms of family income, it is prominent that most of the users belong to the lower income group (35.7%) and middle income group (33.6%). This gives an indication that lower income group and middle income group of the society usually use this AMTS service. See Table 5-7 for more details-

Table 5-7: Socio-economic characteristics of AMTS respondents

Parameters	Absolute values	Relative Values (%)
Total Observation	140	
Sex		
Male	75	**53.6**
Female	65	46.4
Missing	0	0
Age		
Under 25	37	26.4
25-45	43	30.7
45-65	48	**34.3**
Above 65	12	8.6
Missing	0	0
Occupation		
Student	28	**20**
Business/Private service	55	**39.3**
Government Service	13	9.3

Parameters	Absolute values	Relative Values (%)
Retired	6	4.3
Self employed	8	5.7
House wife	22	15.7
Unemployed	7	5.0
Missing	1	0.7
Family Income		
Upto Rs. 8,333 (EWS)	11	7.9
Rs. 8,333-20,833 (LIG)	50	**35.7**
Rs. 20,833-41,666 (MIG)	47	**33.6**
Above Rs. 41,666 (HIG)	19	13.6
Missing	13	9.3

In terms of vehicle ownership, out of total AMTS respondents only 7.9% have their own car while motor scooter is owned by most of them, about 71.4%. See Table 5-8 for further details-

Table 5-8: Vehicle ownership of the AMTS Respondents

Parameters	Absolute values	Relative Values (%)
Total Observation	140	
Car Ownership		
Yes	11	7.9
No	128	**91.4**
Missing	1	2.2
Motor Scooter ownership		
Yes	100	**71.4**
No	39	27.9
Missing	1	0.7

5.2.2 Perception on Service Attributes of AMTS

Likewise BRTS user, AMTS users were asked about the service attributes that have influence to choose this AMTS mode. More than 85.7% respondents pointed out the fare of AMTS which attract them to use this service. Hence, the lower income group of the society finds it affordable because different fare schemes like daily pass, monthly pass, half yearly pass are available at a subsidized rate for the commuters. Around 42.85% and 41.42 % of the respondents indicated about the accessibility to boarding stop and to destination respectively which is one of the reasons for choosing this service. See Table 5-9 for more details-

Table 5-9: People perception about the service attributes of AMTS

Service attributes	Frequency	%
Fare	120	**85.7**
Speed	32	22.8
Frequency	42	**30**
Vehicle cleanliness	42	**30**
Service reliability	8	5.7

Service attributes	Frequency	%
Origin near to stop	60	**42.85**
Vehicle comfort	25	17.85
Service safety/security	8	5.7
Destination near to stop	58	**41.42**
Others	2	1.4

Last but not least, AMTS users were also asked about the reasons for not using the BRTS service although running in the same route of BRTS. Undoubtedly, fare is one of the reasons. Besides, lack of service in origin and lack of service in destination were also mentioned by most users, because missing of one of these two services, either service at origin or service at destination, will result to decline the trip. It is known that AMTS is running on 173 routes whereas BRTS is running on only 12 routes. Therefore, it can be easily concluded that AMTS serves more areas than BRTS which ease the commuter to access to boarding stop and to destination anywhere in the city. In 'others' category some points are aggregated which are: no direct bus by BRTS, extra charge for carrying extra weight in BRTS and so on. See Table 5-10 for more details-

Table 5-10: Reason for not using the BRTS

Service attributes	Frequency	%
Fare	45	**32.14**
Long route	9	6.4
No service in my origin	72	**51.4**
No service in my destination	52	**37.14**
Others	14	10

5.3 Comparative Analysis of BRTS and AMTS Users

In order to conduct a comparative analysis between the users of BRTS and AMTS in relation to their socio-economic and trip characteristics, the characteristics have been divided into 4 major groups to facilitate the analysis which are: socio-economic parameters, trip parameters, accessibility parameters and service parameter. It is to be noted that 184 samples from BRTS user and 140 samples from AMTS user have been used for this comparative analysis. Variables (characteristics) will be discussed based on the relative value (percentage) between the two mode users (See Table 5-11).

There is a clear distinction between the users of BRTS and AMTS in terms of age. For instance, around 45% commuters aged between 25 to 45, mostly working class group, are using BRTS whereas for AMTS, the share is 30.7%. On the other hand, Proportion of motor-scooter ownership for AMTS user is almost similar with that of BRTS user which implies that motor-scooter ownership is increasing among the commuters regardless of their mode use.

Regarding income, the difference is also apparent between the two mode users. For a distinctive classification, four income categories were recoded into two categories namely 'up to lower income group' and 'middle and higher income group' with threshold of income 'Up to 20,833' and 'More than 20,833' respectively. Table 5-11 shows that 48% of the respondents of AMTS from 'lower income group' are using AMTS whereas for BRTS the value is 28%.

Table 5-11: Sample user characteristics of BRTS and AMTS

Variable	Category	Coding	BRTS		AMTS	
			Absolute value	**Relative value (%)**	**Absolute value**	**Relative value (%)**
Total Observation			**184**		**140**	
Socio-economic Parameters						
Gender	Male	1	108	59	75	53.6
	Female	2	75	41	65	46.4
Age	Under 25	1	36	19.9	37	26.4
	25-45	2	82	**45.3**	43	30.7
	45-65	3	52	28.7	48	34.3
	Above 65	4	11	6.1	12	8.6
Car ownership	Yes	1	45	25	11	7.9
	No	2	135	75	128	92.1
Motor-scooter ownership	Yes	1	129	71.3	100	71.9
	No	2	52	28.7	39	28.1
Family income	Up to 20,833(EWS+LIG)	1	49	28.5	61	**48**
	More than 20,833 (MIG+HIG)	2	123	71.5	66	52
Trip Parameters						
Trip purpose	Work	1	89	**57.1**	52	42.6
	School	2	29	18.6	22	18
	Shopping, recreation and Others	3	38	24.4	48	39.3
Trip Frequency	6 days in a week	1	120	**65.6**	71	50.7
	<= 5 days in a week	2	63	34.4	69	49.3
Accessibility Parameters						
Time_boardingstop	Less than 10 minute	1	145	78.8	103	74.1
	More than 10 minute	2	39	21.2	36	25.9
Time_destination	Less than 10 minute	1	132	73.3	106	75.7
	More than 10 minute	2	48	26.7	34	24.3
Mode_boardingstop	Walking	1	130	70.7	96	68.6
	Cycle, motor-scooter & auto-rickshaw	2	54	29.3	44	31.4
Mode_destination	Walking	1	128	70.3	113	80.7
	Cycle, motor-scooter & auto-rickshaw	2	54	29.7	27	19.3
Service parameter						
Service_fare	Yes	1	35	19.2	120	**86.3**

Variable	Category	Coding	BRTS		AMTS	
			Absolute value	Relative value (%)	Absolute value	Relative value (%)
	No	2	147	80.8	19	13.7
Waiting time at stop	Less than 10 minute	1	127	**69**	33	23.6
	More than 10 minute	2	57	31	107	76.4

In trip parameters, trip purpose was assumed to be a prominent variable than occupation because it shows the real activity of the user for which the trip is made. Here, the main focus is given on the working trip and school going trip because usually those trips are made daily which lead to ridership to a specific mode. There is a clear distinction between working trips made by both mode. Around 57 % working trips are made by BRTS whereas for AMTS the value is 42%. Similarly, frequent trips (6 days in a week) are mostly made by BRTS (65.6%) which can be visible from the Table 5-11.

However, users from the both modes have similar accessibility facility. Based on accessibility statistics of BRTS user (see Table 5-4,Table 5-5) access variable were recoded as 'less than 10 minutes' and 'more than 10 minute' while access mode was recoded as 'walking' and 'other modes than walking'. From the Table 5-11, it is clear that the percentage share does not differ so much between the two mode users for all the accessibility parameters.

On the other hand, it can be said that BRTS is providing on time services (less waiting time) which was mentioned by 69% respondents whereas for AMTS the percentage is 23.6%. Waiting time was also recoded into two category-one is 'less than 10 minute', another one is 'more than 10 minute' using the average headway of BRTS which is 10 minutes. In terms of fare, around 86.3% users from AMTS are satisfied with the fare whereas for BRTS the value is 19.2%.

Based on the user perspective for the given trip, it can be concluded that BRTS is able to attract working trip and frequent trip in comparison with AMTS mode which will contribute to BRTS ridership. On the other hand, BRTS fails to attract low income group people. In order to get more insights about the significance of this study, mode choice analysis will be performed in the next section using the above variables.

5.4 A Binary Logit Model for Mode Choice

In the previous section, descriptive analyses were performed on the collected data about BRTS users and AMTS users in relation to their socio-economic profiles and trip characteristics. In order to analyze differences in profiles and behavior of users, simple comparative statistics are usually performed. However, an attempt to investigate the importance of specific variable as opposed to other in the choice of transport mode, a binary logit model for mode choice has been developed. The dependent variable was assumed to be the choice of BRTS relative to AMTS.

In logit model, one category of the dependent variable is chosen as reference category (here is AMTS). All predictor variables in the model are interpreted with reference to it. The coefficients (β) are estimated following an iterative maximum likelihood method. (Ashalatha et al., 2013). Coefficient value (β) infers one unit increase in each predictor variable will affect commuters' choice of BRTS relative to AMTS, when the other variables in the model are held constant. Variables with negative coefficients decrease the likelihood of that response category (BRTS) with respect to the reference category (AMTS) (Field, 2009).

Logit was developed based on the utility theory. The utility for mode i derived from a linear function of the explanatory variables is as follows:

$$V_i = \beta_0 + \beta_1 X_1 + \cdots + \beta_n X_n$$

Where $Vi =$ utility function for mode i

$\beta_1, \ldots\ldots, \beta_n$ are the coefficients associated with explanatory variables

$X_1, X_2, \ldots\ldots, X_n$ are the explanatory variables for mode i

Variables that have distinctive difference in relative value (percentage) between two mode users have been considered for this analysis (see Table 5-11). The selected variables are age, family income, trip purpose, trip frequency, service_fare, waiting time at stop. Car ownership was not included due to its low share for the both mode users. The selected variables have been used as explanatory variables for this mode choice analysis. Only significant variables at 95% confidence interval are shown in the following Table 5-12. Model result reveals the significant influence of income on mode choice. Lower income group people (up to Rs, 20,833) are found to have lower chance of choosing BRTS than AMTS as expressed by a negative coefficient. Similar outcome is also evident for fare, commuters have minimal chance of choosing BRTS relative to AMTS as visible from the high negative coefficient. Therefore, it can be inferred that due to the high fare scheme in BRTS, lower income group are not choosing this service.

Table 5-12: Output of mode choice analysis

Variables	**Coefficient (β)**	**Std. Error**	**Sig.**	**Exp(β)**
Intercept	1.106	0.451	0.014	
Family income= lower income group	-0.883	0.400	0.028	0.414
Trip purpose= work	1.021	0.440	0.020	2.775
Waiting time= less than 10 minute	1.901	0.386	0.000	6.693
Fare= Yes	-3.362	0.418	0.000	0.035

On the other hand, work trip and on time service (less waiting time) are found to have positive influence for BRTS which implies that workers prefer the BRTS over AMTS due to its on time service. Because workers have to maintain their time, usually in peak hours when the congestion becomes severe and simultaneously travel time increases.

It is known that mode choice analysis is a useful predictor for determining ridership of any mode. Based on mode choice analysis between BRTS and AMTS users, it can be concluded that working trip is contributing to BRTS ridership whereas high fare structure is driving the lower income group away.

In terms of model significance, the pseudo R^2 values show the substantive significance of the model. The pseudo R^2 value of the model according to Cox and Shell, Nagelkerke, and McFadden tests are 0.48, 0.64 and 0.47 respectively. Thus, based on the pseudo R^2 values it can be concluded that the selected explanatory variables are able to explain approximately 47–64% variation in the model. However, it should be noted that this analysis is only meant to identify the most influential factors on mode choice based on the combined collected data for BRTS and AMTS users. Model coefficients cannot be used for predictions to a large extent as the data collected has several limitations, namely: total number of sample stations and sample users both are very low; missing values in data are quite apparent, wrong choice of category was made in trip purpose variable during data collection. These discussed issues might have impacts on the model output.

6 Ridership Analysis

It has already been established from relevant literatures that there is a close relationship between transit boarding and built-form indicators and regression is the most used framework for developing a model. A pre selection of indicators (BF indicators) has also been made which will be used to develop the model. In general, this chapter will answer the 2nd objective of the study.

The data used for this study are entirely from secondary sources which contain some GIS generated shape files (feature class). Table 6-1 shows different GIS data files that will be used for achieving the 2nd objective. Except boarding data which was extracted from July, 2015, all other data were sourced from 2008-2010. As Ahmedabad is already a built-up city, over the year the 5D (BF) indicators have not been changing so much. If changes, it is assumed that the growth followed the same pattern over time.

Table 6-1: Available data for the spatial analysis

ArcGIS shape file	Type	Purpose
Population (on TAZ level)	Polygon (spatial and non-spatial)	This file is to determine the population density for each station catchment
Job (block)	Square block (polygon)	This file is to measure the job density for each station catchment
roads	polyline	This file is used to create the station catchment following the network distance and to determine the road connectivity.
Land use	polygon	This file has information regarding different land uses which will be used for diversity measure
BRTS route	polyline	job accessibility by BRTS following this route will be measured
BRTS station	point	This file has information regarding station location from which the catchment will be determined.
Monthly Boarding	Excel format (non-spatial data)	This data will be used as dependent variable in regression analysis

Different BF (built form) indicators have already been discussed along with their corresponding measures. Some relevant literatures on ridership have also been reviewed. Now it intends to operationalize those concepts in this BRTS ridership study. Prior to that, unit of analysis for this study needs to be selected.

6.1 Analysis Unit of Ahmedabad BRTS Study

The station is considered to be the analysis unit for this BRTS study. A station level analysis is more appropriate than route or route segment analysis. However, it requires more detailed data at the station level (Estupiñán & Rodríguez, 2008; Peng et al., 1997).

Now, it is required to identify a service area for each station. A service area (catchment area) around a transit station is broadly defined as the area from which potential riders are drawn. To determine the service area, most researchers depend on the willingness of people to walk or travel to and from a stop. A number of researchers have empirically evaluated the walking distance to transit stops based on the data derived from user surveys (Hsiao, Lu, Sterling, & Weatherford., 1997; Levinson & Brown-West., 1984; Neilson & Fowler., 1972; Zhao, Chow, Li, Ubaka, & Gan, 2003). They have concluded that a one-quarter mile service area from bus stop wouldn't capture all potential users while a large service area will be an overestimation of the number of potential users if distance decay is not explicitly considered. Moreover, estimation of a larger service area will often get a biased result because increasing travel distance to stop tends to shift the commuters to motorized mode (Kimpel, Dueker, & El-Geneidy, 2007).

Regarding this study, a 10 minute walking distance for both access and egress was chosen which was derived from the user survey. It was found that almost 65% potential BRTS users access to and from station within 10 minute by walking. This 10 minute walking distance buffer will therefore be drawn along the road network to identify the catchment area for each station. No distance decay function will be applied here assuming that this distance is willingly travelled by the commuters.

The buffer size was calculated approximate 666m assuming the walking speed 4km/h (Guerra, Cervero, & Tischler, 2011). Buffer area was created along the existing network distance using the 'not overlapping' option. It was assumed that there have been internal competitions among the stations which would mean nearby stations will get smaller service area (Figure 6-1).

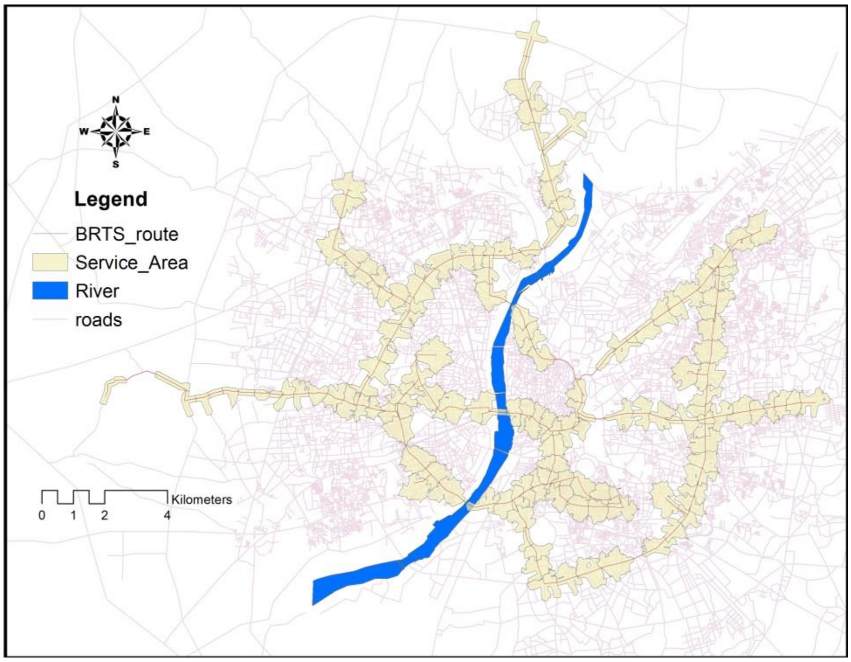

Figure 6-1: Service area of BRTS stations following the road network

6.2 Operationalization of Built Form Indicators

Indicators selected in this study are quantitative in nature and thus each of them has a numeric value. Here, suitable measure from each BF indicator will be identified in terms of data availability and applicability for this study. Each measure will be calculated at each station level by overlaying the 10 minute walking distance buffer except destination accessibility measure which needs further computation. Available measures are grouped from the literature review in the following Table 6-2 .

Table 6-2: Measures for 5D indicators

5D (BF indicators)	Popular measures
Density	Population density Job density
Diversity	Entropy index Dissimilarity index
Design	Intersection density Street density Link-node ratio
Destination accessibility	Job accessibility by BRTS
Distance to station	Distance from nearest station (proxy for catchment size of the stop)

6.2.1 Density

In this study, Density (per acre) was hypothesized to be associated with boarding. Therefore, population density was obtained from the available source TAZ (Traffic Analysis Zone) which has population data for 196 zones. Population density for each corresponding station catchment has been measured by using the 'intersection' function in ArcGIS between TAZ feature class and station catchment. In computations, it has been seen that all the station catchments were not fully covered by TAZ layer. In those cases which catchments have got coverage more than 50% by the TAZ layer, for them density of existing coverage was used to compute the total density for the whole station catchment. For other station catchments having coverage less than 50% were excluded from the analysis. The same procedure was also followed for the estimation of total job density for each station catchment.

6.2.2 Diversity

In addition to density, it's already evident that diversity plays a crucial role in ridership. Diversity in land use has many benefits. Heterogeneous land use can promote trip chaining (combine trips) which would mean different activities within a walking distance can help people to complete many activities in one trip. Besides, more commercial and retail outlets around transit stations would discourage the people not to use private automobile and help people to shop their daily necessities on their way back home from work (Shastry, 2010). On the other hand, homogeneous land use induces sprawl growth which enhances automobile ownership among the residents and simultaneously reduces the transit use.

Although dissimilarity is a better estimator than entropy for land use diversity, entropy index can still be contemplated for this study. As already mentioned, up to one-half mile catchment area, entropy index can give a viable result (Cervero & Kockelman, 1997). Usually entropy is estimated on the basis of share of each land use in the area which can also be referred as 'land use balance'.

Usually selection of land uses depends on the specific study interest (Ma & Chen, 2013; Munshi, 2013). For this study, from a set of eleven land use category shown on land use feature class, six land use category- commercial, industrial, institutional, residential, recreational and mixed use- were considered while computing the entropy index. Mixed land uses have taken into account for this study because a considerable number of mixed uses is apparent along the BRTS corridor. Likewise density, same procedure was followed for diversity measurement when all the station catchments didn't have a full coverage data of land uses. Station catchments having data on land use more than 50% were included in the analysis assuming that they had the same distribution of land uses for the whole station catchment. Table 6-3 shows the existing share of different land use types along the BRTS corridor. Residential land use dominates the area by a large proportion. From

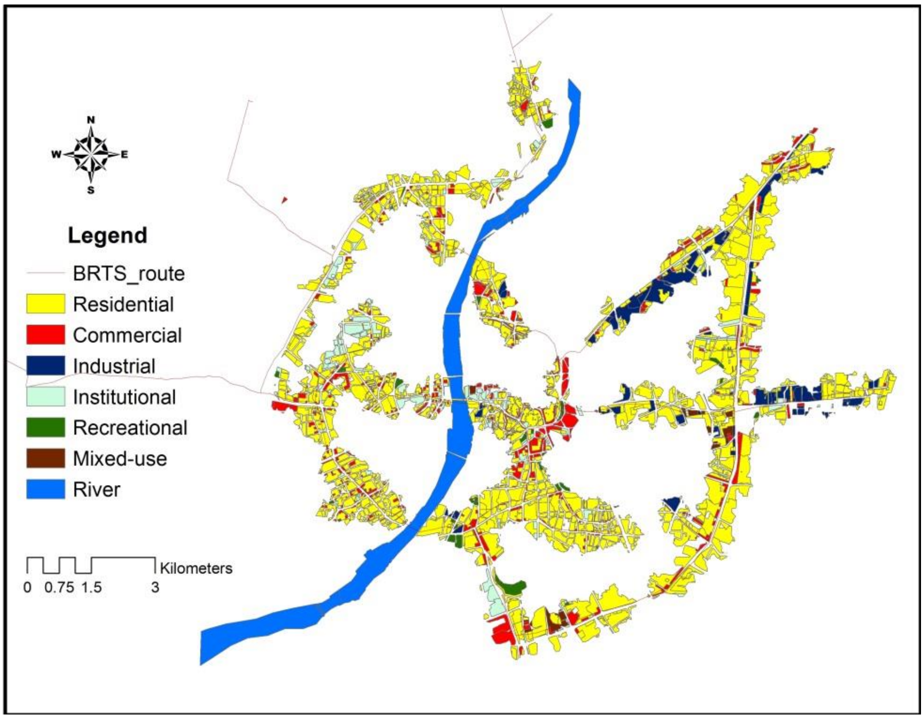

Figure 6-2, it clearly reveals that eastern Ahmedabad (eastern part of Sabarmati river) predominantly has a mixture of residential, commercial and industrial use whereas western part is with mostly residential use.

Table 6-3: Land use distribution along the BRTS corridor

Land use	Area(Acre)	%
Residential	6005.34	73.61
Commercial	816.16	10.00
Industrial	557.20	6.83
Institutional	546.41	6.70
Mixed-use	91.08	1.12
Recreational	142.01	1.74
Grand Total	8158.21	100.00

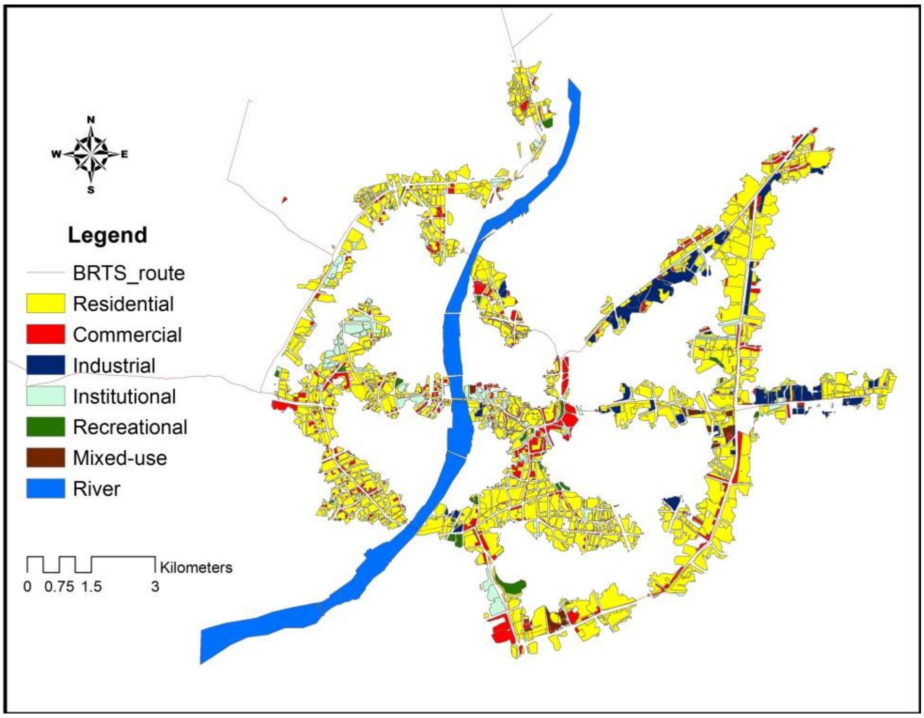

Figure 6-2: Selected land use for diversity measurement

6.2.3 Design

In addition to good land use mix, a good connectivity of the road network is essential for commuters to access in the transit station. The most recommended methods for road connectivity are street density and intersection density. Another measure, link-node ratio is less intuitive because it does not reflect the length of the link. Moreover, Link-node ratio is not corresponding to the actual size or spacing of road network (Cervero & Kockelman, 1997; Ewing & Cervero, 2010).

In this study, intersection density (per acre) was hypothesized to be positively associated with boarding. An intersection having more than 2 legs (connecting lines) was considered for this analysis (see Figure 6-3). Intersections with one connecting line (cul-de sac) and two connecting lines were ignored from the analysis because they are not preferable for good connectivity.

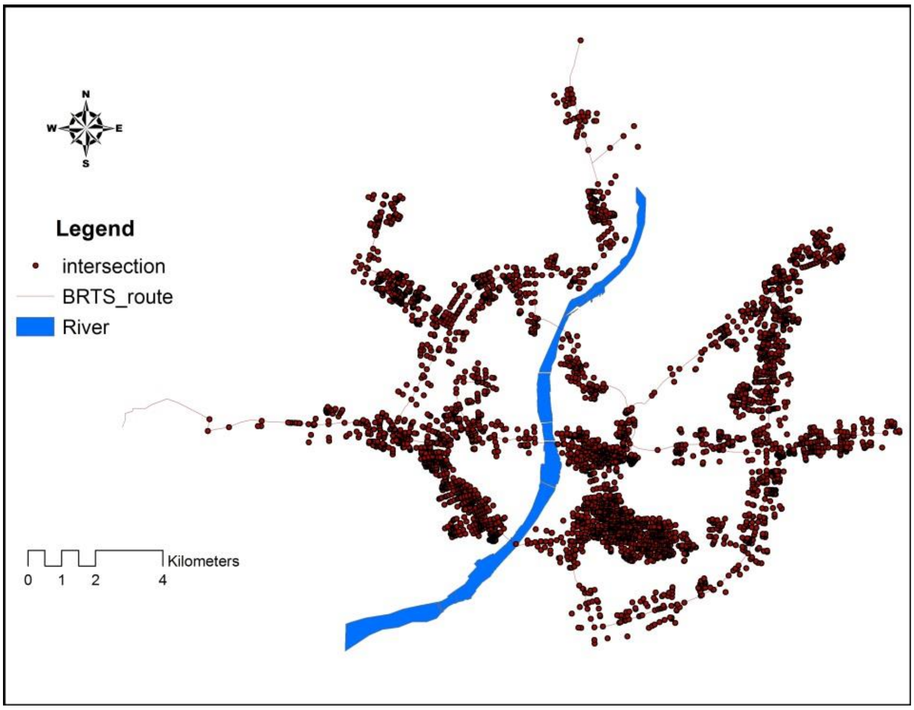

Figure 6-3: More than 2 leg intersection along the BRTS corridor

6.2.4 Accessibility

In the 5D concept, accessibility is measured in terms of destination accessibility. Destination accessibility is usually measured in terms of number of jobs reachable within a given distance (time) threshold. An area in a city from where maximum number of jobs is accessible will have locational advantages to reside in such as city centre. High job accessibility from an area will definitely have an impact on transit use of that area.

To measure the job accessibility from each BRTS station, a threshold of 30 minute travel distance by BRTS was applied along the BRTS road network. This 30 minute threshold was derived from the BRTS user survey which reveals that almost 59% working trips were made with an average journey time of 30 minutes from a BRTS station to the destination BRTS station. The average speed of BRTS, 20 km/h, was applied to draw the network distance over the BRTS route. After applying the 30 minutes threshold from each station, total number of accessible stations from that station was identified and their associated total number of jobs (within station catchment) was counted as well. This number is the total jobs that are accessible from each corresponding BRTS station. The idea behind this job accessibility is that commuters get boarded from their origin station to reach their destination station by BRTS and then walk to their job location within the service catchment of that destination station. However, job accessibility by BRTS is a relative estimation of job from each station because one single job can be accessible from different stations.

6.2.5 Distance to Transit Station

Distance from the nearest station is usually measured considering the idea from Cervero et al. (2010) that the further a station is from the next nearest station, typically the station's catchment area increases in size. But, this measure was not used for this study as same station catchment (10 minute walking distance) was already declared for all stations. Moreover, distance to transit station is not applicable for a BRTS system where all the stations are constructed keeping the same spacing between them just like Ahmedabad BRTS. Ahmedabad BRTS was planned and constructed with an average 500-600m spacing between stations (Bajracharya, 2008).

6.3 Multiple Regression Analysis

After determining the value for all indicators for each station catchment, their descriptive statistics such as mean, standard deviation, minimum, maximum and so on were tabulated to view the data distribution. It was also checked beforehand to identify the discrepancy in data like outlier which was removed accordingly. It is to be noted that out of 151 stations, 116 stations which have value for all indicators were compiled for regression analysis.

Table 6-4: Descriptive statistics of all variable

Variable	Minimum	Maximum	Sum	Mean	Std. Deviation	Skewness
Boarding_July	934	115,760	2,885,604	24,876	23,929	1.882
population_acre	19	357	12,518	108	59	1.495
Job_acre	0.37	298.83	5,373.75	46.33	59.05	2.55
Intersection_acre	0.00	1.28	35.32	0.30	0.23	1.377
Number_jobaccess	69,631	495,977	42,072,949	362,698	100,545	-0.969
Entropy	0.00	0.76	40.64	0.35	0.18	0.072

Table 6-4 presents the descriptive statistics for the dependent variable (monthly boarding in July, 2015) and 5 explanatory variables that will be entered into the regression model. All variables show skewness to some extent. Data with positive value in skewness indicates higher concentration of lower values in the distribution whereas negative skewness represents the opposite. For instance, job density (job_acre) showing maximum positive skewness reveals that most station catchments are having minimal number of jobs while some station catchments occupy maximum number of jobs. This outcome is also consistent with the map output (Figure 6-4) which demonstrates that 80% of the station catchments occupy job less than 61.5 per acre while rest 20% located predominantly in eastern part captures job up to 298.83 per acre. Similarly, number of job accessibility in 30 minutes by BRTS is higher for all station catchments except the station catchments of western periphery (Figure 6-5). It is quite apparent because most of the jobs are concentrated in the eastern part thus having a large number of job accessibility.

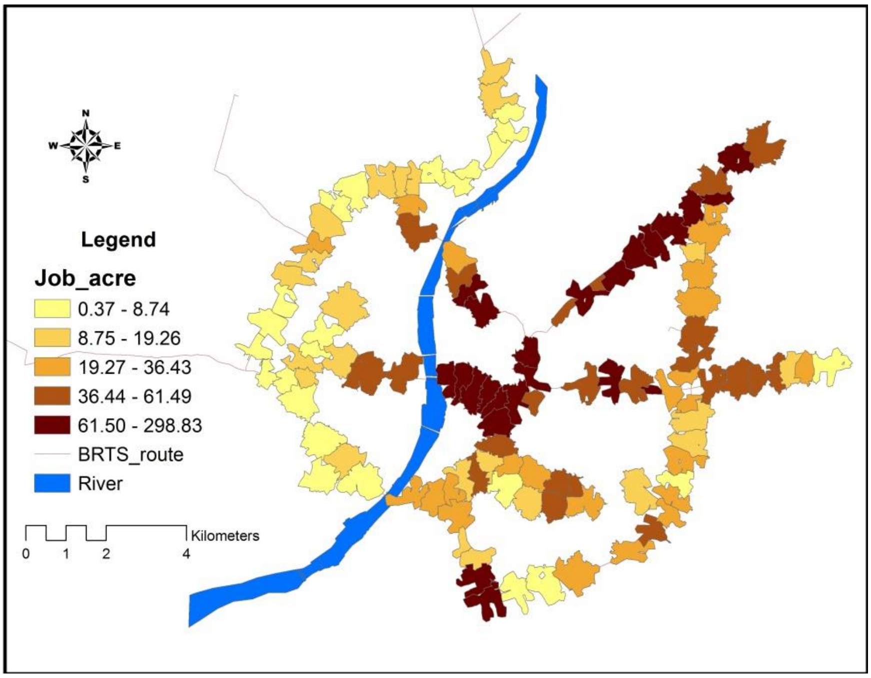

Figure 6-4: Job density (per acre) of each station catchment (equal frequency classification)

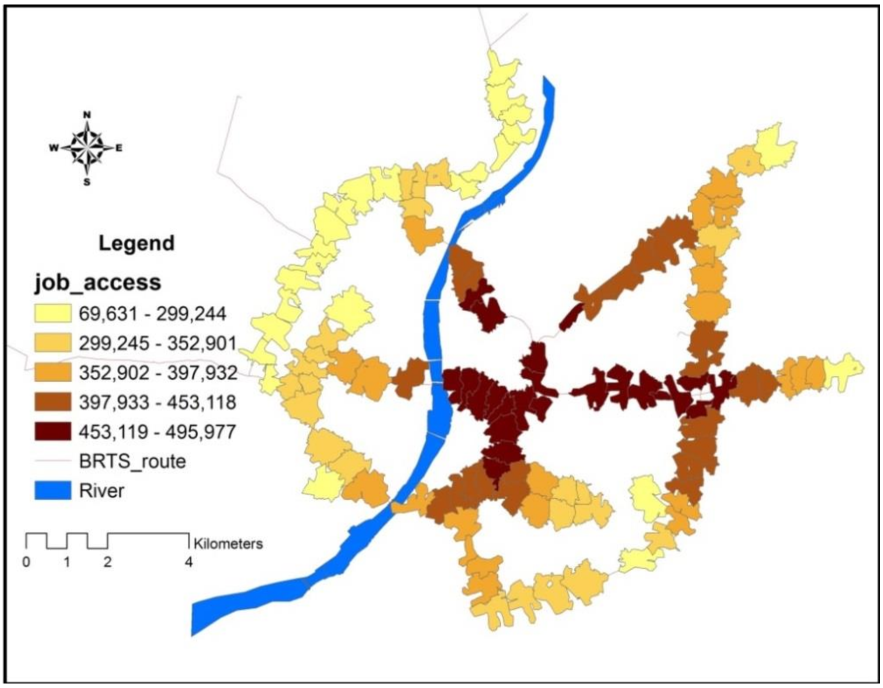

Figure 6-5: Job accessibility in 30 minutes from each station (equal frequency classification)

Similarly, population density was found to be higher in the eastern part of Ahmedabad (see Figure 6-6). Shastry (2010) also found that east Ahmedabad are more densely populated areas in comparison to the western part of the city which has lower and more dispersed residential use. Besides, Munshi (2013) also inferred that locations in east Ahmedabad where accessibility to jobs is high also have higher density of BPL (below poverty level) population indicating that most poor people in the city reside close to their work destinations.

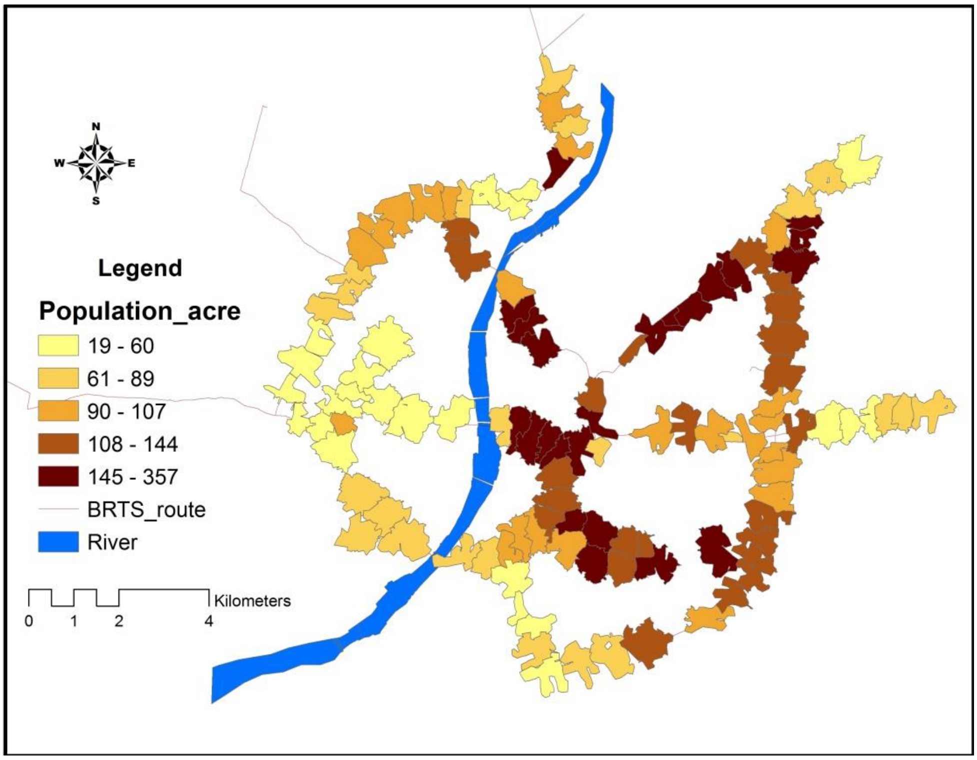

Figure 6-6: Population density (per acre) of each station catchment (equal frequency classification)

In terms of road connectivity, station catchments from eastern part have relatively better connectivity than western part. The top 20% of the station catchments regarding road connectivity were found in both parts (eastern and western) of Ahmedabad (see Figure 6-7). However, using the standard of good road connectivity from Shastry (2010), it can be said that almost 96% (112 out of 116) of the station catchments along the BRTS corridor have lower intersection density (< 0.8 intersection per acre) which implies poor connectivity. Poor connectivity of road network would tend to reduce the ridership of BRTS.

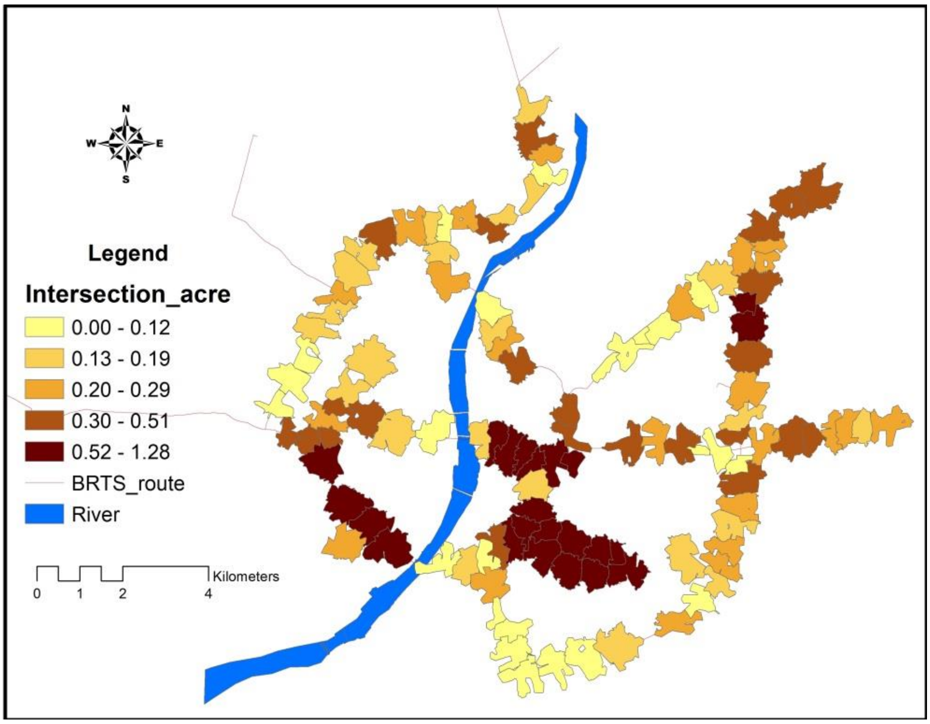

Figure 6-7: Intersection density along the BRTS corridor (equal frequency classification)

Similarly, land use diversity along the BRTS corridor is not showing positive result. From the Figure 6-8 it is clear that most of the regions along the corridor are showing diversity value lower than 0.5 which indicates homogeneity of land use and would not be supportive for enhancing ridership. Moreover, it can be concluded that eastern part of Ahmedabad are more diverse in land use distribution than western part which proves the predominant use of residential in western part.

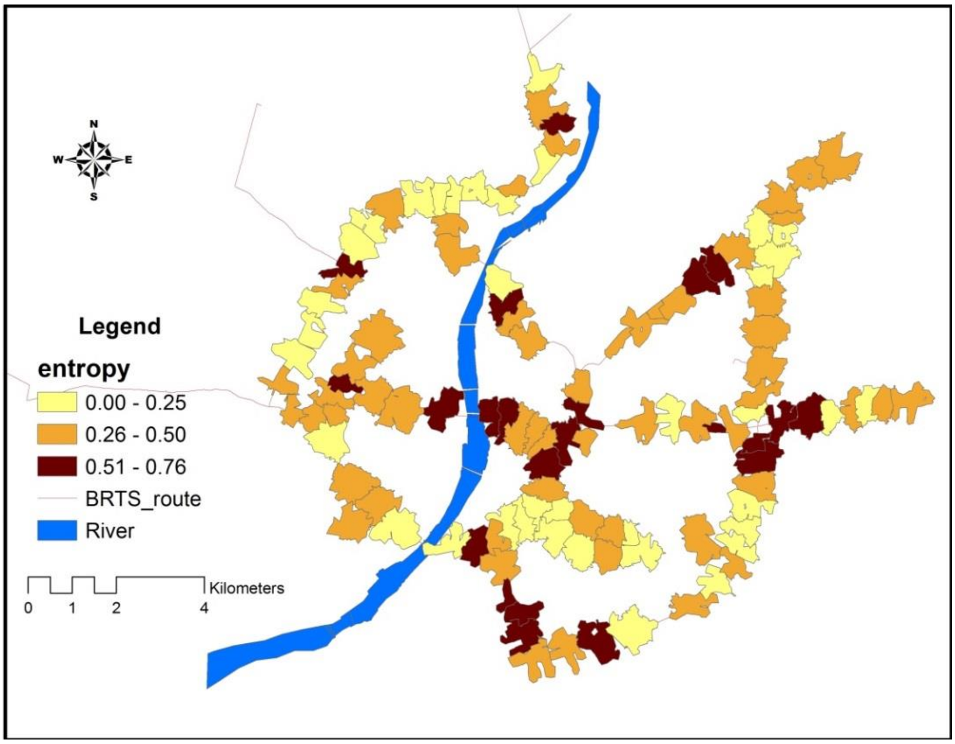

Figure 6-8: Entropy value along the BRTS corridor

On the other hand, from the distribution of monthly boarding (Figure 6-9) it can be seen that out of 116 stations, 80% of the stations have monthly boarding less than 40,212 while rest 20% belong to the boarding class of 40,213-115,760. It also reveals that stations having higher number of boarding mostly concentrated on the western side of Ahmedabad which is predominantly residential use with lower density in population and job.

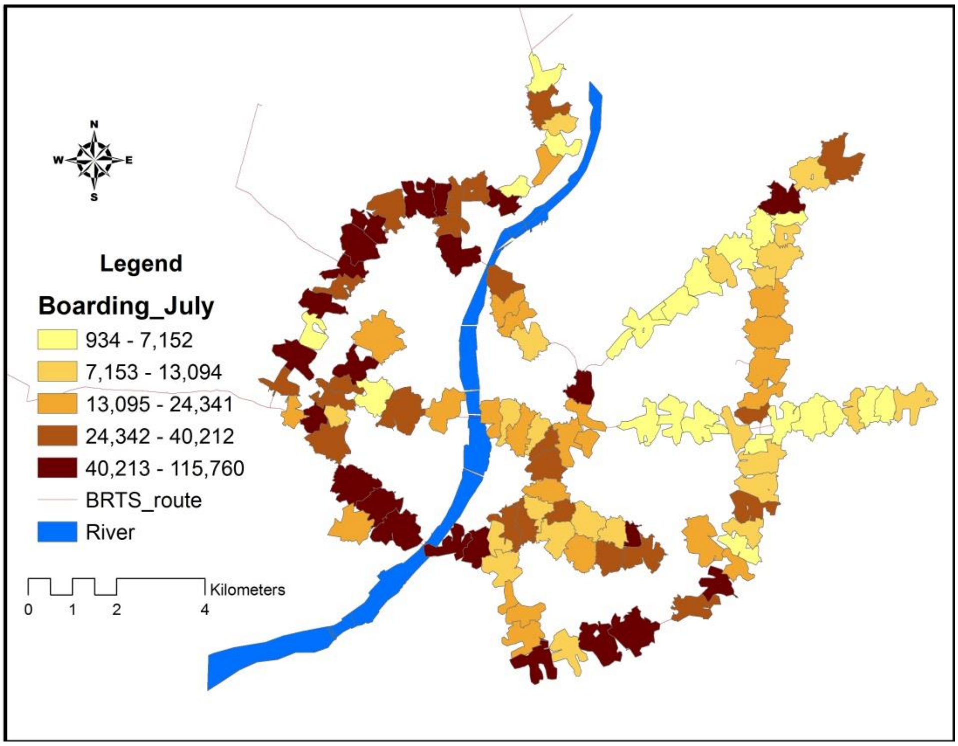

Figure 6-9: Monthly boarding at each station (equal frequency classification)

In order to get a more insight about the influence of explanatory variables over ridership, a regression model was constructed. Prior to that, collinearity among the variables was checked.

Table 6-5: Correlation (Pearson) among the variables

	Boarding	Population_acre	Job_acre	Job_access	Entropy	Intersection_acre
Boarding	1	-0.233^{*}	-0.105	-0.301^{**}	-0.224^{*}	0.007
Population_acre		1	0.484^{**}	0.318^{**}	-0.014	0.269^{**}
Job_acre			1	0.515^{**}	0.370^{**}	0.222^{*}
Job_access				1	0.288^{**}	0.219^{*}
Entropy					1	-0.150
Intersection_acre						1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

From the Table 6-5, it clearly reveals that there is no collinearity issue (<0.8) among the independent variables. Simultaneously, it can be said that relationship between boarding and built-form indicators is very weak and 4 of them are showing negative value.

Table 6-6: Regression model showing coefficient value for all explanatory variables

Model	Coefficients	t	Sig.
(Constant)	66420.64	6.96	0.00
Population_per_acre	-114.66	-2.74	0.01
Job_per_acre	102.59	2.15	0.03
Intersection_per_acre	5859.81	0.59	0.55
Entropy	-31027.51	-2.31	0.02
Job_access	-0.07	-2.78	0.01

Dependent Variable: Boarding

In the regression model (Table 6-6), except intersection density other variables are statistically significant at 95% confidence interval. So the main focus will be given on the significant variables. Except job density which is showing minimal positive coefficient value, other variables reveal negative influence on ridership. The output implies that BF indicators can't fully explain (R^2=0.178) the ridership of Ahmedabad BRTS.

To promote transit use in core urban areas, the Center for Urban Transportation Research (CUTR) at the University of South Florida recommended population density should be higher than 85person/acre (Munshi, 2013). Following this threshold, it was found that almost 39% station catchments are below this cut-off of population density which could have resulted this negative output. Moreover, Ewing & Cervero (2010) also didn't find enough evidence to support the significant relationship of transit use (ridership) with density. They computed weighted average elasticity for transit use from a set of available studies in terms of density and concluded the relationship as mostly inelastic. So it would mean that density does not always have influence on ridership.

In terms of FSI (Floor Space Index), the land is under-utilized along the corridor of BRTS where the average utilized FSI is 0.8 with respect to permissible FSI (2.8) (Shastry, 2010). One of the possible reasons behind this is that transportation plans in India are typically prepared separately from the land use plans by following only the City Development Plan (Munshi, 2013). Under-utilized land is more prone to dispersed and haphazard development. Since the allowed FSI is not fully exploited along the BRTS corridor, that's why the density and diversity indicators can't be able to explain the ridership.

It is already known that BRTS serves a smaller area in Ahmedabad thus having a lower number of job accessibility in comparison with other modes. In terms of total job accessibility, out of 1.67 million jobs in Ahmedabad only 0.52 million jobs can be accessible by the station catchments of BRTS. So, this variable is not able to explain the ridership of BRTS. In many places in Ahmedabad which have most job provisions, there is no service provided by BRTS. From the meta-study done by R. Ewing & Cervero (2010) ,it is known that access to job has the maximum influence on choosing of a specific mode which contributes to ridership of that mode. So it is more likely that people will choose other operational modes rather than BRTS which are providing service on maximum job locations.

Another probable reason behind this minimal relationship between built-form and BRTS ridership is the high travel demand of people in Ahmedabad. In a study, Mahadevia et al. (2012) pointed out that BRTS meets only 1% of travel demand of 30 billion passenger km. So a very limited number of people is using this service. Moreover, high fare scheme, smaller service area are driving the commuters away from BRTS. That's why, this limited number of BRTS riders from each region (station catchment) is not able to make an explicit relationship with built-form.

However, it's already evident from the logit analysis that income is the most influential predictor for choosing a specific mode. BRTS fare was also found to be higher than other mode such as AMTS which is in operation along the same route of BRTS. This is more likely that lower income group people will choose the cheapest mode to travel to their destination if all other variables hold constant. This consequence indicates the need to include income data in this regression analysis. But this is beyond scope for this study due to data unavailability. Besides it is a potential area of improvement in further research. Not only income but also other socio-economic factors like auto ownership could have effects on BRTS ridership (Bajracharya, 2008). Increasing nature of two-wheelers (motor-scooter) ownership in Ahmedabad is very emergent. This factor also needs to be included while developing ridership model for any mode particularly BRTS.

Moreover, station characteristic like transfer station (7 stations in BRTS) from where people can move to anywhere respective to their destination, has significant influence on ridership. It is more likely that people will come from further distances to get boarded in those stations to move their respective destination. Furthermore, 3 railway stations, 2 'GSRTC Bus Terminal' (regional bus terminal) stations, and different cross road stations such as 'Express Highway' station (connection with regional highway), Sola Cross Road, , Ranip Cross Road and so on are attracting more riders because of their locational advantages. The above discussed phenomena have made it less likely the effects of BF indicators on ridership.

Some general limitations can be formulated regarding data quality: all the data in ridership analysis were obtained from multiple sources which are in different formats. Moreover, they were sourced from different year. Errors can be initiated in different stages of data preparation while accumulating and aggregating data. The unavailability of metadata for some indicators had to deal with either by assumption or approximation in some part of the data preparation. Moreover, due to a lack of budgetary situation and timeframe, it was not able to validate data from the field. Analyzing by using those data might have some effects on the resulting output.

Another issue might be the monthly boarding data which was used instead of daily boarding. Monthly boarding is more generalization of boarding data which could not be able to differentiate between week day and weekend boarding. Any week day boarding data will be more suitable for this analysis.

7 Policy Recommendations for BRTS Ridership

In this chapter, more emphasize will be given on the formulation of policy level guideline for BRTS ridership on the basis of findings from BRTS user analysis and ridership analysis. Findings from the user analysis will enable the researcher to develop policy from user perspective. The second analysis (ridership analysis) which has mainly focused on the physical characteristics along the BRTS corridor will enable to formulate policy based on the land use planning along the corridor. In general, this chapter will answer the 3rd objective of the study.

"The trans-vision of Ahmedabad captioned as 'Accessible Ahmedabad' aims to redesign the city structure and transportation systems towards greater accessibility, efficient mobility and lower carbon future" (Ahmedabad Municipal Corporation, 2008b). These concepts are also embedded in the National Urban Transport Policy (NUTP) of India. Similarly, JNNURM (Jawaharlal Nehru National Urban Renewal Mission) which provided the most portion of the financial support for BRTS implementation also draws some objectives with the aim of ensuring accessibility for the urban poor. On the other hand, in Detailed Project Report of BRTS, focus has been given on to promote Transit Oriented Development (TOD) by intensifying land along the corridor to make the city compact. It has also emphasized on to promote non-motorized mobility with proper facility integration for bicycles and pedestrians (Ahmedabad Municipal Corporation, n.d.). In support of these visions, some policy recommendation will be formulated based on the findings made from this study.

7.1 Policies from User Analysis

Affordable fare for the poor: It is already evident that BRTS is not affordable to the urban poor in comparison to other modes. Although there is a discounted smart card available for students, there is nothing for the economically lagging community of the society. In order to make it affordable for the urban poor, different fare schemes could be introduced at a subsidized rate like day pass, monthly pass which are existent in AMTS mode. This type of schemes will also be useful for the frequent (daily) user of BRTS such as workers.

Increasing accessibility to BRTS: Accessibility to the public transit has a crucial role in determining its ridership. This is determined by the number of routes and the location of the stations and their coverage (service area) (Bajracharya, 2008). From the BRTS user survey, it is apparent that a substantial number of BRTS riders is coming from 10 minute walking distance and a very few is from further distances using other modes predominantly auto-rickshaw. So it is clear that BRTS is unable to attract people from further distances. To enhance the commuters from further distances, 'MYBYK'- a bike share system, an initiative by Greenpedia Bike Share Pvt. Ltd., has already been installed at 9 BRTS stations as a pilot program which will be upgraded periodically in all stations based on concurrent performance. Commuters can rent a bike at a subsidized rate to access to and from the station. The system couldn't get popularity yet due to a lack of infrastructure for biking. Moreover, the system is not integrated with the BRTS system in terms of fare ("MYBYK-BikeShare," n.d.).

It can therefore be recommended on the proper installment of this 'bike share' system in all stations. Moreover, 'MYBYK' should be integrated with BRTS to promote this bike-share system by providing incentive in the form of subsidized fare for the bike users.

Increase of service route of BRTS: Increase of service route might be a possible option for BRTS ridership increase. Currently, BRTS is running on only 12 routes in Ahmedabad which is very low than other competitive modes. Moreover, BRTS is not providing services in major job locations. It is already evident that missing of service either at origin or at destination will decline the trip by commuters. From the expert consultation meeting with Janmarg, it is known that there is no further plan for route extension and they are now working only for the improvement of accessibility of BRTS stations. If accessibility can be increased to a large extent from each station, there might have some potentials to develop connections to important destinations and activity centre (job) as well.

7.2 Policies from Ridership Analysis

Utilization of full FSI: It has already been observed from USA study that when development concentrates along corridor, transit patronage increases (Cervero et al., 2010; Kuby et al., 2004). But in Ahmedabad context, the relationship is missing which may be due to a lack of utilization of land along the corridors. One of the recommendations that can be contemplated through this analysis is to increase the density and diversity along the BRTS corridor. An increase in density can be done by increasing the height of buildings and hence the FSI. TOD (Transit Oriented Development) type development can be recommended along the BRTS corridor because TOD proposes land use mix integrated with a walkable environment to public transportation (Center for Transit-Oriented Development, n.d.). TOD can be implemented by acquiring the land from the owner. But at present there is no mechanism developed yet which allows acquiring and developing land. Moreover, policies like parking policies, zoning policies restrict the provision of development (Shastry, 2010). There should be some mechanism to provide supports to developers for developing land along the BRTS corridor site and to create a market for this development as well. A plan needs to be approved immediately to support these mechanisms.

On the other hand, lower intersection density along the corridor implies poor connectivity to BRTS station. Proper measures need also to be considered for the implementation of safe and convenient access way such as pedestrian way with proper connections. These measures should be integrated with the TOD development along the BRTS corridor.

These policy recommendations discussed above are general policy formulated from the research findings. No matter, which strategy will be used, there is always a need of proper planning to make it successful. Besides, it requires an efficient governing body who will dictate in every phase of planning, designing, and implementation.

8 Conclusion and Recommendation for Further Research

8.1 Conclusion

This chapter of the study will present here the outlines of all findings made as per the objectives of this research. Recommendations for further relevant research that could be taken into consideration for future decision making and policy formulation will be discussed afterwards.

The main goal of the research is to evaluate the performance of Ahmedabad Janmarg BRTS on the basis of its ridership. Since its introduction, it has achieved worldwide accolades due to its increasing ridership and least effect on environment. But still a number of issues needs to be taken into consideration for a successful BRTS implementation. Accessibility has been given as one of the most priorities for BRTS ridership. It will also be able to ensure accessibility to important job locations. This comprehensive project should also ensure equity at the forefront by incorporating the lower income group for being recognized as an inclusive sustainable transportation system in developing countries.

As per the specific objective, the following specific conclusions can be drawn:

1. **To develop a user analysis for Ahmedabad Janmarg BRTS**

In order to assess the BRTS ridership based on user perspective, a revealed preference survey was conducted from the users of BRTS and AMTS. Survey was designed by incorporating socio-economic characteristics, trip characteristics and as well as some service criteria. From the descriptive statistics, it is clear that majority of BRTS users own motor-scooter which is not a positive sign for BRTS ridership. Moreover, BRTS can't be able to attract riders from further distances as most of the users are coming from 10 minute walking distance. A logit model was developed afterwards which shows that work trips are mostly made by BRTS rather than AMTS and BRTS is providing on time service (less waiting time). On the other hand, lower income group people are not choosing BRTS due to its high fare scheme as compared to AMTS.

2. **To conduct the ridership analysis using the built-form indicators**

In order to assess the ridership based on the Built form indicators (5D), a proper methodology was developed for the quantification of 5D indicators. The use of appropriate techniques in GIS helped to analyze the spatial data effectively which were used as input in regression analysis. From the literature, it was anticipated to have some relation between built-form indicator and ridership but in this study, it was found totally absent. Moreover, land use diversity, road connectivity and job accessibility by BRTS were found to be in poor condition. Some other emerging factors like income, auto ownership need to be incorporated to have a better understanding of ridership. Some stations like transfer station, railway station, cross road station are producing more ridership which might affect this ridership analysis. However, with respect to total travel demand, BRTS serves a very small population which is probably not adequate to make an explicit relationship with built-form.

3. **To develop a policy recommendation for Janmarg BRTS in line with the existing policy**

Policies are accumulated based on the findings from user analysis and ridership analysis in conformity with the existing policy. Revision of fare for the poor was given first priority. In terms of accessibility, proper emphasize was given on the introduction of effective access mode so that people can access to BRTS station from further distances. On the other side, Full utilization of FSI was emphasized by applying the TOD measures along the BRTS corridor. In order to implement all the policy recommendations, there is a need of proper planning and an effective governing body who will dictate in every step of planning, designing, and implementation.

8.2 Further Research

The research is the first of its kind in Ahmedabad context that presents empirical evidence on the evaluation of ridership of Ahmedabad BRTS. Besides, several problems were encountered in the operationalization of this research. Some of these were resolved during the course of research and some still remains to be analyzed in future research. This research also opens up new horizons to be researched further in any Asian city context on the same topic. Several areas for future research are proposed in the following-

Use of remote sensing image: The methodology followed in this research needs reliable data sources that have a direct association on the output. This research had to depend upon multiple sources for data collection such as land use, road network that could be derived from the remote sensing data. In addition, the quality of data was one of the limitations of this study that can be improved by validating the data from the remote sensing image. Remarkable advancement in remote sensing data and the ability to process the data using top-class software and technology could possibly make the data sources available in future. There is a large degree of potential to use remote sensing image for the quantification of the heterogeneous nature of land uses along the BRTS corridor. Moreover, it is required to quantify the heterogeneity of use in all floors which is very much apparent for mixed land uses. Then, land use balance (Entropy index) could be considered in ridership analysis taking into account the uses in vertical space.

Inclusion of socio-economic variables: Built form (5D) and the BRTS ridership relation is very weak statistically which means built form is only able to explain a small portion of variation in BRTS ridership. Now, it is required to incorporate other variables that have probable impact on ridership like socio-economic status of people. For instance, zone wise income class (per capita) of people or auto-ownership rate might have significant influence on BRTS use. In Ahmedabad, many transit services are in operation and hence are competing to attract the riders. Mode choice analysis can be further improved by incorporating other modes which are running in the same route of BRTS. Without proper mode choice analysis by incorporating all pertinent variables, no ridership analysis can be fully accomplished.

Survey design for the households along the corridor: This study was limited to BRTS and AMTS user survey that were incorporated in the mode choice analysis. Moreover, the built-form indicators along the corridors are not able to explain the ridership. So, to have a better representation of the travel behavior of people, the survey design could be further upgraded for the households along the BRTS corridor as they are the potential users of BRTS. To have a better understanding of the mode choice behavior of people, a stated preference (SP) survey could be designed with effective selection of choice sets. This will also enable the researcher to identify that to what extent people are willing (likelihood) to shift towards BRTS. The outcome of this SP survey will help the policy makers and planners to improve the service of BRTS.

Subsidiary research on access mode: Further research can be anticipated on the feasibility study of introducing access modes particularly bike in all BRTS stations. Commuter perception about the existing performance of bike-share system will enable the researcher to improve this system in a more effective way. Proper design guidelines could also be outlined for a possible access network based on the existing access pattern (desire line) of the commuters.

Full-fledged ridership analysis: In order to have a better understanding of the relationship between built-form indicators and ridership, a full-fledged ridership analysis can be conducted by using the boarding data for all available modes for each region (service catchment). Because, with respect to total demand, the limited number of riders of BRTS and their socio-economic status does not probably enough to make a conclusive relation with built-form.

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Appendix-I (Questionnaire for BRTS user)

This survey is a part of a MSc research entitled 'Evaluation of Bus Rapid Transit System Based on Ridership Analysis: A Case Study of Ahmedabad Janmarg BRTS' at the Faculty of Geo-information Science and Earth Observation (ITC), University of Twente, the Netherlands under the ongoing cooperation with CEPT University. The purpose is to investigate BRTS user characteristics and their trip characteristics. Ten samples of regular users will be interviewed from each sampled BRTS station. The information obtained in this survey will be accorded confidential treatment and will be used for academic purposes only.

Date & Time-	**Survey ID-**	**Station name-**

Interviewee Information (Socio-economic):

Gender □F □M

Age □Under 25 □25-45 □45-65 □Above 65

Disabled □Yes □ No

Highest education level □Primary school □Secondary school □College □University □others……………….

Main occupation □Student □Business □Government service □ Private service □ Retired
□ Unemployed □ others…………………

Monthly Household (family) income □ upto Rs. 8,333 □ Rs. 8,333 to Rs. 20,833 □ Rs 20,833 to Rs 41,666 □ above Rs. 41,666

Do you have a private car?
□Yes □ No

Do you have a motor scooter/motor cycle?
□Yes □ No

Trip characteristics:

What is the purpose of your trip?
□ To work □ To school □ Recreation □ To shopping □ others…………….

Which is your boarding BRTS station?
…………………………………..

How much time does it generally take to come to the boarding BRTS station from your origin?
□ less than 5 minutes □ 5 -10 minutes □ 10-20 minutes
□ 20-30 minutes □ more than 30 minutes

Which mode do you usually use to come to the boarding BRTS station?
□ walking □ cycle □ motor-scooter/motor-cycle □ auto-rickshaw
□ others…………….

How much is the waiting time at boarding BRTS station?
□ 0-5 minute □ 5-10 minutes □ 10-15 minutes □ others……………

How much time does it take to reach the final station from boarding station?
□ less than 15 minutes □ 15-30 minutes □ 30-45 minutes
□ 45-60 minutes □ more than 60 minutes

Which is your final BRTS station?
……………………………………

How much time does it generally take to reach your destination from the final BRTS station?
□ less than 5 minutes □ 5 -10 minutes □ 10-20 minutes
□ 20-30 minutes □ more than 30 minutes

Which mode do you usually use to reach your destination from the final BRTS station?
□ walking □ cycle □ motor-scooter/motor-cycle □ auto-rickshaw
□ others……………..

How often do you make this trip?
□ Everyday (6 days in a week) □ ………………..days in a week □ ………………..days in a month
□others……………………

Which features of services attract you to use the BRTS? (More than one answer is possible)
□ Fare □ Speed □ Frequency □ Vehicle cleanliness □ Vehicle comfort (not crowded) □ Service reliability (on time) □ Service safety/security □ Origin near to BRTS station □ Destination near to BRTS station □ others…………………………□ others………………………

Do you have any suggestions to improve the service? (More than one answer is possible)
□ Fare □ Speed □ Frequency □ Vehicle cleanliness □ Vehicle comfort (not crowded) □ Service reliability (on time) □ Service safety/security □ others………………………□ others………………………

Thanks for your kind cooperation.

Appendix-II (Questionnaire for AMTS user)

This survey is a part of a MSc research entitled 'Evaluation of Bus Rapid Transit System Based on Ridership Analysis: A Case Study of Ahmedabad Janmarg BRTS' at the Faculty of Geo-information Science and Earth Observation (ITC), University of Twente, the Netherlands under the ongoing cooperation with CEPT University. The purpose is to investigate AMTS user characteristics and their trip characteristics. Ten samples of regular users will be interviewed from each sampled AMTS stop. The information obtained in this survey will be accorded confidential treatment and will be used for academic purposes only.

Date & Time-	**Survey ID-**	**Stop name-**

Interviewee Information (Socio-economic):

Gender □F □M

Age □Under 25 □25-45 □45-65 □Above 65

Disabled □Yes □ No

Highest education level □Primary school □Secondary school □College □University □others……………….

Main occupation □Student □Business □Government service □ Private service □ Retired
□ Unemployed □ others…………………

Monthly Household (family) income □ upto Rs. 8,333 □ Rs. 8,333 to Rs. 20,833 □ Rs 20,833 to Rs 41,666 □ above Rs. 41,666

Do you have a private car?
□Yes □ No

Do you have a motor scooter/motor cycle?
□Yes □ No

Trip characteristics:

What is the purpose of your trip?
□ To work □ To school □ Recreation □ To shopping □ others…………….

Which is your boarding AMTS stop?
…………………………………..

How much time does it generally take to come to the boarding AMTS stop from your origin?
□ less than 5 minutes □ 5 -10 minutes □ 10-20 minutes
□ 20-30 minutes □ more than 30 minutes

Which mode do you usually use to come to the boarding AMTS stop?
□ walking □ cycle □ motor-scooter/motor-cycle □ auto-rickshaw
□ others…………….

How much is the waiting time at boarding AMTS stop?
□ 0-5 minute □ 5-10 minutes □ 10-15 minutes □ others…………..

How much time does it take to reach the final stop from boarding stop?
□ less than 15 minutes □ 15-30 minutes □ 30-45 minutes
□ 45-60 minutes □ more than 60 minutes

Which is your final AMTS stop?
…………………………………

How much time does it generally take to reach your destination from the final AMTS stop?
□ less than 5 minutes □ 5 -10 minutes □ 10-20 minutes
□ 20-30 minutes □ more than 30 minutes
Which mode do you usually use to reach your destination from the final AMTS stop?
□ walking □ cycle □ motor-scooter/motor-cycle □ auto-rickshaw
□ others……………..
How often do you make this trip?
□ Everyday (6 days in a week) □ ………………..days in a week □ ………………..days in a month
□others……………………
Which features of services attract you to use the AMTS? (More than one answer is possible)
□ Fare □ Speed □ Frequency □ Vehicle cleanliness □ Vehicle comfort (not crowded) □ Service reliability (on time) □ Service safety/security □ Origin near to AMTS stop □ Destination near to AMTS stop □ others…………………………□ others………………………
Do you have any suggestions to improve the AMTS service? (More than one answer is possible)
□ Fare □ Speed □ Frequency □ Vehicle cleanliness □ Vehicle comfort (not crowded) □ Service reliability (on time) □ Service safety/security □ others………………………□ others………………………
Why don't you use the BRTS? (More than one answer is possible)
□ Fare □ Long route □ No service in my origin □ No service in my destination □Others……………..

Thanks for your kind cooperation.