“PERFORMANCE EVALUATION OF BRTS BY USING AHP MODEL”

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It is certified that the work contained in this dissertation thesis entitled '**Performance evaluation of BRTS by using AHP model** submitted by **Khushbu Maheshbhai Bhagat**, **Enrollment No.: 180041001** studying at Civil Engineering Department, Faculty of Engineering & Technology, for the award of M.Tech (Name of Branch-Specialization) is absolutely based on his/her own work carried out under my/our supervision and that this work/thesis has not been submitted elsewhere for any degree/diploma.

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Dedicated

To,

My family, friends and teachers for support and encouragement

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Research brings about dramatic changes in the traditional lookout of Science & Technology. It has widened our vision, opened newer avenues and lightened the dark obscure facts of mysterious universe. Behind every success there are lot many efforts, but efforts are fruitful due to hands making the passage smoother. I express my deep sense of gratitude for hands, people extended to me during my work.

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Place: Atmiya University, Rajkot **- Khushbu M. Bhagat**

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"PERFORMANCE EVALUATION OF BRTS BY USING AHP MODEL"

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ABSTRACT:

This paper presents the development of bus route evaluation system, for a public bus transportation system in Rajkot city of Gujarat. Bus mass rapid transit System (BRTS) is an innovative, high capability, lower price transport solution which will considerably improve urban quality. Transport System in most Indian cities is rapidly deteriorating due to the increasing travel demand and inefficient transportation. There square measure numerous issues connected with transport such tremendous increase in range of accidents, Environmental degradation, Congestion, Overcrowding as a result of inadequate system, Frequency of service and schedule isn't strictly adhered. the matter of pollution, safety and unskillfulness have reached at an awful level in most of the key cities in Bharat as a result of intense growth of its population -both of individuals and motorcars, combined with inefficient transport system and poor social control of environmental laws etc. Analytic Hierarchy Process (AHP) model is used, which integrates quantitative and qualitative attributes of the bus routes.

KEY WORDS: BRTS, Qualitative and quantitative criteria, AHP method.

CHAPTER 1: INTRODUCTION

1.1 General:

In India traffic is heterogeneous in nature where a variety of vehicles travel over a single road with variable speeds. Lack of mass transportation facilities tends to increase more usage of private vehicles and intermediate para-transit vehicles. All these combine makes the roads of city very congested and lead to increase in travel time, also increasing pollution very rapidly. Urban population in India has increased significantly from 62 million in 1951 to 285 million in 2001 and is estimated to be around 540 million by year 2021.

Another interesting phenomenon is constantly increasing number of metropolitan cities and their population. The number of metropolitan cities that are those with million plus population was only 5 in 1915 and by 2001; their number has jumped to 35. This number is expected to increase by 51 by the year 2021. The number of people living in Indian metropolitan as much as 107.88 million or 37.80 percent of the total urban population and these numbers are likely to grow in the coming years.

Public Mass Transportation System is a key component for development and growth of country. This system faces problem in almost all the developing countries. Due to lack of financial and other important resources, it restricts the investments and funding for construction, maintenance and up gradation of existing as well as new transport system. Inefficient public transport systems in India tend to various problems like accidents, traffic congestion, pollution, heat island effect, environment degradation and overcrowding. Public Transport systems need to be safe, reliable, efficient, affordable and effective. BUS RAPID TRANSIT SYSTEM (BRTS) may be one such solution to overcome the problem.

1.2 BRTS- An introduction

The concept of BRTS took its birth in Curitiba in mid 1970s. it was developed by Jaime Lerner, former mayor and was called 'SURFACE METRO'. There is no perfect definition of Bus Rapid Transit (BRT). Wright (2005) defines it as a "bus based mass transit system that delivers fast, comfortable and cost-effective urban mobility".

Rapid transit is not a transport mode as such, but, it is means of mass transportation offering a faster service than the alternatives which are available, typically with average operating speeds of 50 kmph or more; this generally requires an exclusive rights of way.

Bus Rapid Transit System (BRTS) is an innovative, high capacity, lower cost public transport solution that can significantly improve urban mobility.

Bus Rapid Transit gives communities the best bang for their buck when it comes to investing in transit.

1.3 Characteristics of BRTS

- Segregated right of way
- Constructed on at grade level, easy to build up
- Inexpensive as compared to metro rail
- Automatic tracking of buses available
- Crossing is only available at zebra crossings, resulting in low fatality rates

1.4 Historical development of BRTS

Bus Rapid Transit (BRT), also called a bus way or transit way, is bus-based public transport system designed to improve capacity and reliability relative to conventional bus system. BRT aims to combine the capacity and speed of metro with the flexibility, lower cost and simplicity of a bus system.

The first BRT system in the world was the Transit way system in Ottawa, Canada, which entered service in 1973.

As of March 2018, a total of 166 cities in six continents have implemented BRT systems, accounting for 4,906 km of BRT lanes and about 32.2 million passengers every day, of which about 19.6 million passengers ride daily in Latin America, which has the most cities with BRT systems, with 54, led by Brazil with 21 cities. The Latin American countries with the most daily ridership are Brazil (10.7M), Colombia (3.06M), and Mexico (2.5M). The other regions, China (4.3M) and Iran (2.1M) also stand out. Currently, TransJakarta is considered as the largest BRT network in the world with approximately 251.2 kilometers of corridors connecting the Indonesian capital city.

1.5 BRTS in India

Government of India has laid emphasis on creating SMART cities across the country. Smart transportation systems can act as major contributor in success of such proposal. BRTS fulfills this basic criterion. In future, BRTS will be flagship system in Indian cities' public transport system. Bus rapid transit system (BRTS) is a bus rapid transit in India. The first BRTS in India is Rainbow Bus Rapid Transit System in Pune, started in 2006.

In India, currently BRTS is functioning in Ahmadabad, Indore, Jaipur, Rajkot, Bhopal, Delhi, Pune, Vijayawada and Rajkot.

1.6 BRTS in Rajkot

To provide mass transportation facility to citizens of Rajkot, planning for 63.50 km BRTS corridors was done, which includes round the city Blue corridor of (length 29.00 km), inside the city Red corridor joining East and West ends of (length 18.00 km) and Green corridor joining North and South ends of (length 16.50 km). In which Blue corridor was planned in three phases.

- On 150 feet ring road from Gondal circle to Jamnagar road-10.70 km
- From Jamnagar road circle to Green land circle-9.14 km
- From Green land circle to Gondal road circle-9.16 km

Further pilot Blue corridor phase-1 project of cost Rs. 110 crore was submitted by Rajkot Municipal Corporation under Jawaharlal Nehru National Urban Renewal Mission (JNNURM) to Govt. of India, which got sanctioned in July 2007. From the above mentioned, the construction work of Blue Corridor Phase – 1 on 150 feet ring road is completed. After successful trial runs, on 1st Oct 2012, BRTS bus service opened for citizens of Rajkot which is 2nd BRTS in India in operation.

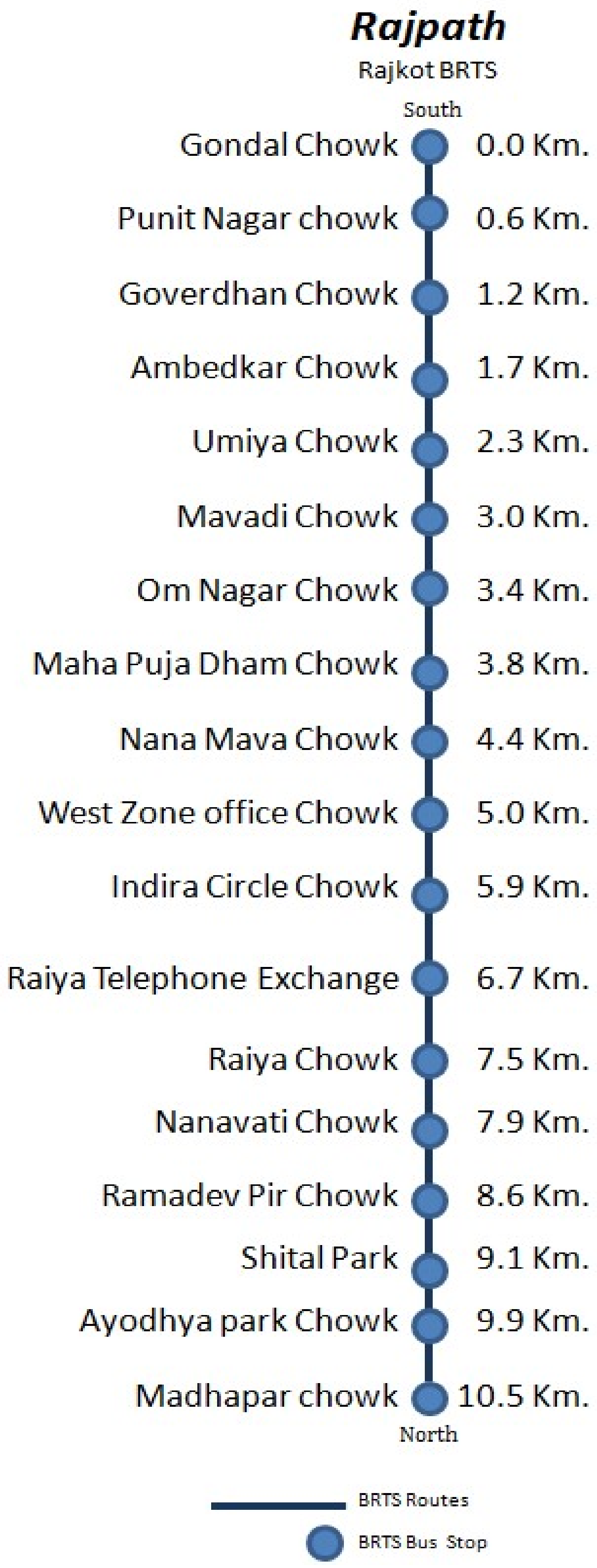


Fig.1.1 Operational Blue Line Transit Map

1.7 Problem statement

Transportation is becoming a major issue for many cities and an important part of the economic development of the city. Due to increased traffic, congestion, stress related longer commute times and vehicle emissions, cities today are becoming increasingly concerned with improving their transit service to encourage more drivers to switch to public transport.

With growing urbanization, the government has realized the need for smart cities in urban area that can cope with the challenge of urban living and also be magnets for investment to increase economic development, reduce costs, enhance quality of life and provide smart mobility. Smart mobility requires smart public transport System.

Population and traffic issues of Rajkot city are increasing day by day so by evaluating the performance parameters of existing operational corridor we can improve efficiency for future.

1.8 Objectives of study

I. To evaluate and analyze the performance of existing BRTS within the study area.
II. Recommend appropriate measures for improvements.

1.9 Scope of study

- To study about the different parameters which affect the performance of BRTS.
- Collection of all data for analysis by performing necessary surveys.

1.10 Summary

- This chapter describes overview of the thesis of BRT system, need of study, objectives and scope, the next chapter explain the basic information.

CHAPTER 2: LITERATURE REVIEW

2.1 General:

In order to summarize the current knowledge in the area under investigation a thorough understanding of review is carried out for identifying any advantages and disadvantages of in previous work so helping you to identify them in my own research and eliminates potential weakness and potential strength.

2.2 Research Work

- **Tisa v. Agarbattiwala & Bhasker Vijaykumar Bhatt studied on "Performance Analysis of BRT System Surat"**-(2016). Their objective of study was to analyze performance of BRTS to encourage people to use BRTS efficiently. They analyzed system by service quality and user satisfaction survey. They took two corridors for study and they got passenger travel information from records of tickets issued from each of the bus stations for the duration of November 2015 till February 2016 – a time passage of 4 months. They did this exercise for both corridors for same time duration. Then they took sample survey considering total population travelling in the Surat BRTS. The respondents were requested to provide responses through a questionnaire seeking details and exercise resulted in formulation of an O-D Matrix for groups of stations. Based on the O-D Matrix, maximum daily trip occur from different group of stations were figured out. And different questions responded by the commuters during the user-satisfaction survey were compiled and analyzed.

- **Gautam Raj G, Ch. Ravi Sekhar and S. Velmurugan studied on "Micro simulation Based Performance Evaluation of Delhi Bus Rapid Transit Corridor"**- Their study area was Delhi BRT corridor from the junction of signal-controlled Mehrauli - Badarpur Road (near Ambedkar Nagar) and runs on J. B. Tito Marg in South Delhi and ultimately terminating before Moolchand Hospital Intersection on the Inner Ring Road. They collected data of traffic volume by CVC survey at all the intersection, speed and delay data by conduction survey using Probe Vehicle Method by fitting GPS during different time periods so as to account for the peak and inter peak hour traffic separately, signal phasing data was collected at all the intersections on study area to know the cycle lengths at different intersections and its corresponding number of phases. These parameters mainly include vehicular characteristics, traffic flow composition, desire speed distributions, vehicle flows and composition, and driving behavior parameters namely car-following and lane change behavior. And they developed performance models in the form of Speed versus Volume-Capacity ratio.

- **Taotao Deng and John D. Nelson studied on "Bus Rapid Transit implementation in Beijing: An evaluation of performance and impacts"**- In China, BRT schemes are being adopted as a key strategy for relieving traffic problems. As a case-study, this paper examines the performance and impacts of BRT in Beijing, the first full-featured BRT system in China. It considers in turn the role of ITS technology in influencing the operational efficiency, technical performance and cost issues associated with BRT. Particular attention is given to the consequent impacts of BRT on travel behavior change, traffic environment and property development. While some challenges remain, the early performance of BRT suggests that it is one of the key measures for promoting sustainable mobility.

- **Akhilesh Chepuri, Rakesh Kulakarni, Manraj Singh Bains, shriniwas Arkatkar and Gaurang Joshi studied on "Evaluation of BRTS corridor in India Using Microscopic Simulation: A Case study of Surat city"**- The present study consists of the evaluation of traffic flow characteristics on a 1.8 Kilometers of BRTS corridor in Surat city, which includes four intersections. The work aims to evaluate the delays caused to the traffic at intersections using the microscopic simulation software, VISSIM 7.0. The work also comprises of system performance evaluation of BRTS, which includes investigation on causes of delay and overall its impact on the BRTS. The study is carried out for suggesting the feasible traffic management measures, which may result in reduction of delay and travel time to both BRTS buses and private traffic, which may eventually result in emissions reduction.

- **M Sudheer Babu and V. Mahalakshmi Naidu studied on "BRTS PERFORMANCE AND EVALUATION OF VISHAKHAPATNAM"**- Their study area was PTC corridor- Pendurthi to Dwarakanagar via NAD junction (22.60km), i.e. via Pendurrthi-Gopalapatnam- NADKancharapalem-Railway Station-Dwarakanagar Bus Station and STC corridor-Pendurthi to Dwarakanagar via simhachalam (20.40 km), i.e. via vepagunta-Simhapur Colony Road-Gosala-Adivivaram-Hanumanthawaka Junction-Hanumanthawaka junction-Maddilapalem-Dwarakanagar Bus Station. They carried out traffic volume studies. They evaluated system on the basis of traffic volume studies, journey speed studies and average spot speed studies.

- **Satiennam T. et al. 2006, "A study on the Introduction of Bus Rapid Transit system in Asian developing Cities: A case study on Bangkok Metropolitan administration Project"-** They Studied on the introduction of bus rapid transit system in Asian developing cities. The purpose of the study was to introduce several strategies to support BRT implementation inn Asian developing cities, such as a strategy to appropriately integrate the para transit system into BRT system as being a feeder along a BRT corridor to supply demand. These proposed strategies were evaluated by applying demand forecasting and emission models to the BRT project plan of Bangkok metropolitan administration (BMA) in Thailand. It was demonstrated that the proposed strategies could effectively improve the BRT ridership, Traffic conditions, and air pollution emission of the entire system in Bangkok. The study could be further extended to include strategy recommendation if a BRT system were to be introduced to other Asian development cities.

- **Shah Shaishav studied on "Appraisal study of BRTS Surat- A sustainable urban Transport"-** 2015 urban transport system is the key issue in today's scenario due to incredible growth rate in urban areas and improper planning to accommodate incoming migrants. Surat city being the diamond capital and textile hub become an epicenter for opportunities which in turn attracts a great number of man-power. This huge population and increasing requirements toward transportation challenges the existing service in the heart of the city. To face this challenge, BRTS turns out as sustainable transit system looking toward the availability of space and existing network of roads. Paper deal with assessment of less preferred existing operational BRTS phse-1: Corridor-1 i.e. Udhana Darwaja-Sachin GIDC which doubts its feasibility and requires thorough analysis to highlight its flaws. Also, Congestion and connectivity has been the concerned issue and need to be resolved by re-planning to eliminate the flaws and sustain the tough three-wheeled competitor.

- **Agrwal P.K., Gurjar KJ. & Gupta V. studied on "Evaluation of socio-economic Impact of city bus services in developing countries"**-(2016) They said that Bus rapid Transit System (BRTS) is a pioneering, high capacity, lower cost public transport solution that can significantly improve urban mobility. They discuss about the need of BRTS in Indian cities as central Business districts have continued to grow that require more capacity and improved access. They also discuss the positive and negative impacts of BRTS. BRT system can often be implemented fast and incrementally. For a given distance of dedicated running way, BRTS is generally less costly to build than rail transit. BRTS can be the most cost-effective means of serving a wide variety of urban and suburban environments. BRTS can provide quality performance with enough transport capacity. BRT system can utilize a wide range of vehicles, from standard buses to specialized vehicles. A wide variety of ITS technologies can be integrated into BRT system to improve system performance in terms of travel times, reliability, convenience, operational efficiency, safety and security. Designing a service plan that meets the needs of the population and employment centers in the area and matches the demand for services is a key step in defining a BRT system. Saving travel time. By creating segregated bicycle lanes and redesigning intersection, conflicts between motorized traffic and bicyclist can be reduced leading to a sharp decrease in the number of accidents and fatalities for bicyclist and motorized two-wheelers. Exclusive travel ways result in to increased capacity.

2.3 Main features of bus rapid transit system

Dedicated lane: - Only separate lanes makes for travel faster and ensure that buses are not delayed by mixed traffic congestion. Separate rights of way may be elevated, in a cutting, or in a tunnel, possibly using former rail routes. Transit malls or ‘Bus streets’ may also be created in city centers.

Bus way Alignment: - Center of roadway - only corridor keeps buses away from the busy curb-side, where cars and trucks are parking, standing and turning.

Off Board fare collections: - Fare prepayment at the stations, instead of on board the bus, eliminates the delay caused by passengers paying on board.

Intersection Treatment: - Prohibiting turns for traffic across the bus lane significantly reduces delays to the buses, Bus priority will often be provided at signalized intersections to reduce delays by extending the green phase or reducing the red phase in the required direction compared to the normal sequence. Prohibiting turns may be the most important measure for moving buses through intersections.

Platform level Boarding: - Stations platforms should be level with the bus floor for quick and easy boarding, making it fully accessible for wheelchairs, disabled passengers and baby stroller, with minimal delays.

REVIEW ON BUS RAPID TRANSIT SYSTEM

Bus rapid transit system has the potential to provide a higher quality experience than possible with traditional bus operation due to reduce travel and waiting times, increased service reliability and improved usability. Today bus rapid transit system (BRTS) in various forms are in operation in more than 70 cities around the world, and being planned in dozens more. The increased interest in bus Rapid Transit System (BRTS) is the result of its ability to deliver high performance transit services at relatively low costs, with short implementation times and high positive impacts. Bus Rapid Transit System (BRTS) is a bus-based transit system which allows higher speed, improved capacity and better bus safety by segregating them from another road way traffic into a separated bus way (Levinson et al. 2003. Bus Rapid Transit System gives scalable solution for providing better mobility, easy accessibility, Comfortable and safer service, at lower costs using efficient utilization of limited resources, energy and land. As more and more cities throughout the world opted for Bus Rapid Transit System (BRTS), further work into Bus Rapid Transit System design and performance has made BRTS evolve into an advanced and enhanced "Bus" system with increasingly flexible and adaptable, Operational and service characteristics. More than 150 cities in the world now operate BRTS corridor. However, discussions remain for BRTS i.e. which features are better and in which manner is it better.

Types of Bus Rapid Transit System

There are three type of bus rapid transit system

A. Open BRTS – The open system, the existing bus services are upgraded by providing dedicated lanes for movement of buses in the congested areas of cities. The system is thus flexible and easily adapts to the existing bus routes and movement pattern.

B. Closed BRTS – Buses run on a dedicated corridor without the public transport being affected by the mixed traffic.

C. Hybrid BRTS- In hybrid BRTS, BRTS service is extended to the areas where dedicated corridors are not there. The system thus is flexible to the existing travel pattern in the city and also provides more frequent services to the areas served by exclusive BRT routes.

Road safety design guidelines for Bus rapid transit in Indian cities. EMBARQ India, Draft version 2018, General design recommendations the results from their research have influenced our general design recommendations for BRT systems. We conclude that the safest BRT systems should have the following features: Central BRT lanes, as opposed to Kerb side bus lanes

-Segregated BRT lanes, as opposed to simple lane marking indicating a busway

-BRT plying in the regular direction as mixed traffic, rather than counter flow 13

-Restriction on right turns for mixed traffic across the BRT lanes.

-Signalized pedestrian crossings at frequent intervals, and physical measures to prevent jaywalking

-Centralized BRT authority, to regulate BRT driver performance, with respect to speeding and traffic violations.

-Physical speed control measures for mixed traffic lanes.

The design speed:

Speed is the single most important causal factor in road accidents that result in a road fatality. Often, road designers incorrectly apply highway standards to urban roads. Urban roads cannot neglect the mobility and accessibility requirements of all road users, including that of pedestrians and NMT. As argued earlier, in the urban Indian context, there is a high volume of pedestrian, NMT and other slow-moving traffic. Furthermore, the abundant edge development that characterizes most urban roads in India, creates the need for even motor-vehicles to slow down in order to access these properties. This puts them into conflict with the fast-moving through-vehicles. 40 kmph for any road upon which a BRT is developed. As far as possible, this speed should be induced through road design, rather than relying on signage and/or enforcement. These design features include narrower lanes, speed tables, chicanes, etc. A combination of these features is utilized in various templates in these Guidelines. It is important to note that in the urban context, achieving a high midblock speed has very little impact on total journey time. This is because of the frequent need to slow down or stop at intersections, which are present at a much more frequent interval than in the context of a regional highway. Further, a slower and more consistent speed, may also improve the capacity of the road. This is because the safe gap or headway needed to be maintained between vehicles is less for slower moving traffic. Thus, the space requirement for slower moving traffic is less, and this allows a higher density of vehicles on the road. Up to a certain point, this higher density is associated with a higher throughput volume on the road, beyond which congestion sets it.

The BRT Standard, Institutes for transport development and policy (ITDP), 2016 edition, Bus rapid transit (BRT) is a bus-based rapid transit system that can achieve high capacity, speed, and service quality at relatively low cost by combining segregated bus lanes that are typically median aligned with off-board fare collection, level boarding, bus priority at intersections, and other quality-of-service elements (such as information technology and strong branding). The BRT Standard is an evaluation tool for BRT corridors based on international best practices. It is also the centerpiece of a global effort by leaders in bus rapid transit design to establish a common definition of BRT and to ensure that BRT corridors more uniformly deliver world-class passenger experiences, significant economic benefits, and positive environmental impacts. The Standard functions as a planning tool, a scoring system, and a means of achieving a common definition of BRT. By defining the essential elements of BRT, it provides a framework for system designers, decision makers, and the sustainable-transport community to identify and implement high-quality BRT corridors. The BRT Standard celebrates cities that are leading the way in BRT excellence and offers best practice-based guidance to those planning a system. Certifying a BRT corridor as basic BRT, bronze, silver, or gold places it within the hierarchy of international best practices. Cities with certified BRT corridors are beacons of progress that have adopted a cutting-edge form of mass transit, elevating urban transport to a new level of excellence while making communities more livable, competitive, and sustainable. The elements that receive points in the BRT Standard have been evaluated by BRT experts in a wide variety of contexts. When present, these elements result in consistently improved system performance and have a positive impact on ridership. Being certified as gold or silver, however, does not necessarily imply that a corridor is costly or complicated, since many BRT features are low cost or even no cost. Even relatively simple systems can achieve a high score if care is given to design decisions. From Belo Horizonte, Brazil, to Yichang, China, cities that have built gold-standard BRT have seen significant benefits to commuters, revitalized city centers, and better air quality.

The following terms are important to understanding BRT:

Active Bus Control: A bus operations system that uses data from automatic vehicle location (AVL) systems, which are based on global positioning system (GPS) information, to allow for bus service adjustments to be made in real time, often through an automated process;

Arterial Street: A major transportation thoroughfare designed for longer distance trips within a city;

Bus way Alignment: The location of transit lanes within the right-of-way on a street;

BRT Corridor: A section of road or contiguous roads served by a bus route or multiple bus routes with a minimum length of 3 kilometers (1.9 miles) that has dedicated bus lanes and otherwise meets the BRT basic minimum requirements;

Direct Service: A BRT service pattern where multiple bus routes operate in a BRT corridor busway as well as outside the BRT corridor. This allows passengers to make trips with fewer transfers than with conventional trunk and feeder services;

Frequency: The number of buses that arrive in a given length of time on a single bus route or on a street segment (including multiple routes). For the purpose of the BRT Standard, the deductions for low frequencies (large headways) are measured by bus route—for example, on the Trans Oeste corridor in Rio de Janeiro, Brazil, the frequency for buses on the Expresses (express) routes is around 30 buses per hour.

Grade-Separated: When a transportation corridor is designed so that users do not cross direct paths of users on the corridors that it crosses. Grade separation is achieved by separating transportation corridors vertically. A flyover and an underground metro are two examples of grade separation;

Headway: The length of time between buses either on a single bus route or on a street segment (including multiple routes). For the purpose of the BRT Standard, the deductions for low frequencies (large headways) are measured by bus route—for example, on the Trans Oeste corridor in Rio de Janeiro, Brazil, the average headway for the Expresses (express) buses is two minutes, meaning that buses on that route arrive every two minutes;

Right-of-Way: The width of public space dedicated to the movement of people and goods as well as other public uses;

Spur: A stretch of BRT infrastructure that branches off a BRT corridor but is not long enough to be considered a corridor by itself, as it is less than 3 kilometers (1.9 miles) in length;

Trunk and Feeder Service: A BRT service pattern where all BRT bus routes operate only along the BRT corridor (the trunk route) and feeder bus routes take people to and from BRT stations. Passengers must transfer between feeder routes and BRT trunk routes.

The BRT planning guide, institute for transportation development policy (ITDP), 4th edition, in this book Volume 1 lays the groundwork for initiating a Bus Rapid Transit (BRT) system from the initiation of a project to sparking real momentum that will bring the project into reality. BRT systems have become increasingly popular as a cost-effective way for cities around the world to provide high quality transit. However, it is crucial to the success of a project's development that a driven and committed group of people advocate for BRT (Chapter 1), explain how the system 16 works and the reasons why it is needed (Chapter 2), and capture the necessary political commitment and leadership to catalyze a fully comprehensive setup and planning process (Chapter 3). Project teams will need to look at a number of factors that are described in detail in Volume I, as these will determine the BRT system potential for success. These include: capital and operating costs, performance, flexibility, scalability, implementation speed, and the impact the system will have socially and environmentally on the immediate surroundings of the system as well as the metropolitan region as a whole. The first three chapters of the BRT Planning Guide delve into these factors among others while providing examples of how advocates, governments, and citizens alike have provided the vision, leadership, and action to see the project through and launch a successful BRT system.

Ahmedabad BRTS: Ahmedabad Municipal Corporation has incorporated "Special Purpose Vehicle" called Ahmedabad Janmarg Ltd in order to run and to operate BRTS buses. Ahmedabad Janmarg Ltd is registered under Companies Act, 1956 and is 100% subsidiary of Ahmedabad Municipal Corporation. In order to provide faster, reliable, ecofriendly and advanced Public Transportation Ahmedabad Janmarg Ltd is committed to operate and run BRTS services for the citizen of Ahmedabad. As per the MOA, Municipal Commissioner is the Chairman of the Ahmedabad Janmarg Ltd and following are the Board of Directors of the company. Ahmedabad Janmarg Ltd is responsible to operate buses, to decide fare, to maintain bus lanes and to maintain bus shelters. Ahmedabad Janmarg Ltd also gets advertisement rights across BRTS route and provides Pay & Park facilities to the citizen of Ahmedabad. It is designed by CEPT University. It was inaugurated in October 2009. The network expanded to 89 kilometers (55 mi) by December 2017 with daily ridership of 3, 49,000 passengers. BRTS won several national and international awards for design, implementation and operation. It was rated Silver on BRT Standard in 2013.

Jaipur BRTS: In principle approval' of Rs 469 crore was given by government of India (GoI) in august 2006 for implementation of 42 km of BRTS phase-I corridor in Jaipur city. Sanctioned cost of BRTS Phase-I is 479 crores.

JDA has been assigned the responsibility for BRTS infrastructure creation and Jaipur City Transport Services Limited (JCTSL) (a Special Purpose Vehicle (SPV), joint venture of JDA & JNN) has been entrusted with the Bus Operations.

In August 2006, the Jaipur Bus Rapid Transit Service was approved by the Indian government for implementation. The responsibility for managing Jaipur BRTS has been given to JCSTL, a Special Purpose Vehicle formed by Jaipur Development Authority and Jaipur Nagar Nigam in a joint venture. The BRTS is expected to cater to city's growing traffic for next 15–20 years. In Phase I, two corridors have been proposed.

- Sikar Road to Tonk Road – North-South Corridor
- Ajmer Road to Delhi Road – East-West Corridor

A section of North-South Corridor from C-Zone Bypass near Harmada to Pani Pech became operational in July 2010. The work on other section of North-South Corridor and East-West Corridor has commenced.

Pune BRTS: Rainbow BRTS is a bus rapid transit system in the twin cities of Pune and Pimpri-Chinchwad, in Maharashtra, India. The system is operated by the Pune Mahanagar Parivahan Mahamandal Limited (PMPML). The infrastructure has been developed by the Pune Municipal Corporation (PMC), Pimpri-Chinchwad Municipal Corporation (PCMC). The project currently envisages 113 km of dedicated bus corridors along with buses, bus stations, terminals and intelligent transit management system.

The Rainbow BRTS project is being implemented with the financial support of Jawaharlal Nehru National Urban Renewal Mission (JnNURM) of the Government of India. Additionally, specific components of the project in Pimpri-Chinchwad are being funded under the 'Sustainable Urban Transport Project', which is an initiative of the Ministry of Urban Development, Government of India and is supported by The World Bank, UNDP & GEF.

Bhopal BRTS: Bhopal BRTS is a bus rapid transit system being built to serve the Indian city of Bhopal, located in the state of Madhya Pradesh. The construction is funded by the Central Government under its flagship JnNURM. Unlike most of BRT projects in India which are designed to cater the transportation needs of suburban parts of the city, Bhopal BRTS is designed mainly to serve the Central business districts(CBDs).It started its operation n with a fleet of just 30 buses in 2006, after receiving JnNURM Sanction, has grown to 225 buses comprising AC and Non AC Low Floor Buses. 80 Bus Stops are being built along the 24 km long corridor. Rampbuilding for most of the Stops is underway and Bhopal Municipal Corporation is likely to complete the work by June 2013. Also, one part of corridor, which runs through Misrod to RRL may start working by 31 March 2013. A trial run was conducted earlier and minor difficulties have been sorted out. These Bus-Stops will have Display-Boards with the information of incoming Buses and siting arrangements will be made for the passengers. A 2-door system will help safe ride for the passengers, where one door will open only when the Bus arrives and another door will open only if the person carries a valid ticket. The stops are being built on PPP, where the contractor will be responsible for maintenance of the Stops and in-turn will have to right to put up advertisements and earn revenue.

2.4 Summary

A critical review of the literature indicated that there are various deficiencies in the present state of the art for evaluating the performance of BRTS.

CHAPTER 3: STUDY AREA

3.1 General

Rajkot is the fourth largest city in the state of Gujarat, India, after Ahmedabad, Surat, and Vadodara. Rajkot is the center of the Saurashtra region of Gujarat. Rajkot is the 35th-largest urban agglomeration in India, with a population more than 1.2 million as of 2015. Rajkot is the seventh cleanest city of India. Rajkot is also the 147th-fastest-growing city in the world. The city contains the administrative headquarters of the Rajkot District, 245 km from the state capital Gandhinagar, and is located on the banks of the Aji and Nyari rivers. Rajkot was the capital of the Saurashtra State from 15 April 1948 to 31 October 1956, before its merger with Bombay State on 1 November 1956. Rajkot was reincorporated into Gujarat State from 1 May 1960.

3.2 Geography

Rajkot is located at 22.3°N 70.78°E. It has an average elevation of 128 meters (420 ft.). The city is located on the bank of Aji River and Nyari River which remains dry except the monsoon months of July to September. The city is spread in the area of 170.00 km^2. Rajkot is situated in the region called Saurashtra in the Gujarat state of India. The significance of Rajkot's location is owing to the fact that it is one of the prime industrial centers of Gujarat. Rajkot has a central location in the area called the Kathiawar peninsula. The city is located within the Rajkot district in Gujarat. Rajkot city is the administrative headquarters of the district of Rajkot. The district is surrounded by Bhavnagar and Surendranagar in the east, Junagadh and Amreli in the south, Morbi in the north and Jamnagar in the west.

3.3 Climate

Rajkot has a semi-arid climate, with hot, dry summer from mid-March to Mid-June and the wet monsoon season from mid-June to October, when the city receives 590 mm of rain on average. The months from November to February are mild, the average temperature being around 20 °C with low humidity.

3.4 Role of Transportation in Rajkot

The Gujarat State Road Transport Corporation (GSRTC) runs regular buses to and from Rajkot to other cities of Gujarat. More than 81000 people travel daily with GSRTC. Rajkot is very well connected with Gujarat State Highways and Rajkot is allocated the vehicle registration code GJ-3 by RTO. There are a number of private bus operators connecting city with other cities of Gujarat state and other states of India. The fast-industrial development, farm-related production connected with rise in population over the past ten years has added has given in a large-scale increase in traffic in the city. Day to day increasing strength of traffic has resulted in the visible some problems like traffic jam, delay, crashes, pollution etc. which presents in a showy and fake way a possible threat to the money-based energy and productive of the city. The Rajkot city has a dense road network. Because of the concentration of different commercial and industrial activities in Rajkot and surrounding towns. The Rajkot city road network is leading to the surrounding towns is heavily crowded. The network includes NH-8B (NH 27), State Highways (SH-26, SH-27, and SH-42) and District Roads. Rajkot city has a two-ring road the influence area, in terms of travel demand, covers the income districts of Rajkot. There is heavy inflow and outflow of traffic from the area into the city. The Jamnagar, Gondal railway lines pass through middle of Rajkot City. The role of public transport system for intra city passenger travel is not important. Rajkot's major transport system depends on three wheelers, locally known as 'shuttle'. Intra-City bus services are running by State Transport and private bus operators. Most of the mini buses are operated by private operators. Transportation is the spine to the development of city-based areas. As a result, public transport financially less viable, speed reduce and crowding and blockage levels increase and the transportation becomes source of environmental problems. Vehicles are major source of city-based air pollution. Traffic transportation services and road networks are key indicators to provide the image of city, so to design the plan for Rajkot city is a very critical exercise and because of this it is carried out exactly.

Fig.3.1 City map of Rajkot

3.5 Study Area

The Blue corridor which is currently in operation from Gondal chowk tp Madhapar chowk is selected for BRTS performance evaluation. Its map is as shown below.

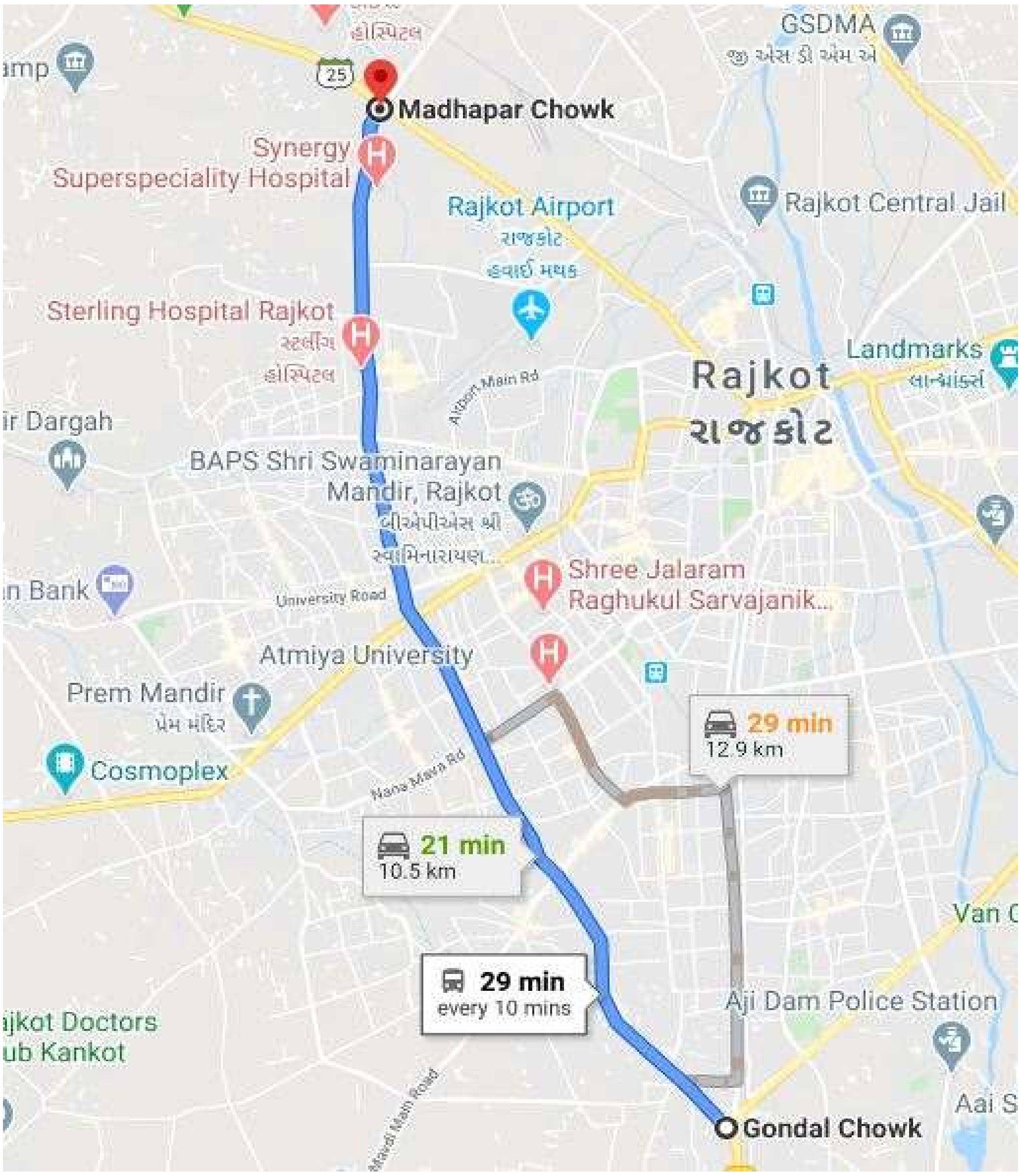


Fig.3.2 Google map of study area

3.6 Population Growth

Rajkot is the fourth largest city in Gujarat. Rajkot is the 35th largest urban agglomeration in India, with a population more than 1.2 million as of 2015. (Source: Census2011.co.in)

Table 3.1 Population Growth of Rajkot City

Year	Population	Growth rate
1961	194145	47.00
1971	300112	+54.58
1981	445076	+48.30
1991	559407	+25.69
2001	1002000	+79.12
2011	1390640	+38.06

(Source RMC)

3.7 Vehicle Growth

All vehicles are registered during purchase, and the Regional Transport Office maintains of the number and type of vehicles registered every year. The recent way things are going of vehicle registration is available with the RTO, which can be used to evaluate the vehicle population. Another way is to manage and do traffic amount counts at each intersection. So, the daily traffic quantity in the city can be extracted and projected for future years. The vehicle population for this study has been collected by both methods to crosscheck and arrive at a figure. Table 4.2 shows the total vehicle population category-wise for the past thirty years.

Table 3.2 Vehicle Growth in Rajkot City

Sr. No.	Types of Vehicle	1981-1991	1991-2001	2001-2011
1	Two-wheelers	1,45,450	3,70,581	5,30,623
2	Auto rickshaw	3,334	7,162	11,122
3	Cars	15,665	33,280	60,734
4	Buses	1,099	2,418	1,376
5	Goods vehicles	20,364	28,382	39,507
6	Tractors	7,032	15,051	13,394
7	Other vehicles	510	813	3,139
Total		**1,93,454**	**4,79,017**	**7,10,234**

(Source RTO, Rajkot)

3.8 Summary

In this chapter, brief description of Rajkot city and details of selected BRTS Route and its drawing is included.

CHAPTER 4: METHODOLOGY

4.1 General

Methodology is a structured set of methods, practices, processes and procedures used to attain. The methodology is the general research strategy that outlines the way in which research is to be undertaken and, among other things, identifies the methods to be used in it. These methods, described in the methodology, define the means or modes of data collection or, sometimes, how a specific result is to be calculated. Methodology does not define specific methods, even though much attention is given to the nature and kinds of processes to be followed in a particular procedure or to attain an objective.

4.2 REQUIREMENT OF PUBLIC TRANSPORT SYSTEM IN SMART CITIES

According to the report on 'India's Urban Awakening' by McKinsey Global Institute, In The next 20 years, India will have 68 cities with a population over one million up 42 cities from today. Hence, due to intensified growth of population India face number of significant hurdles that continue to obstruct the development of urban infrastructure, land valuation challenges, capability gaps, and funding shortfalls that is effectively holding India back from a new round of dramatic economic growth. Therefore, India requires an efficient and sustainable solution to facilitate the planning, construction, Management and smart services in urban areas using latest technologies. Smart city is a new concept and a new model, which applies the new generation of information technologies. The main challenges are for developing smart cities in India are to pursue convenience of the public service; delicacy of city management, livability of living environment, smartness of infrastructures, and long-term effectiveness of network security. Public transport system is a key technology to resolving these challenges. Table No 3.1 present benchmark for public transport system in smart cities.

Table 4.1 Basic requirements of public transport

Sr. No	Basic requirement	Benchmark for public transport in smart cities
1	**Smart mobility**	▪ The time required for travelling from one point of the city to another point should not exceed 30-45 minutes in smart cities.
2	**Smart accessibility**	▪ The maximum walking distance to stops in smart cities should not exceed 300-500 m
		▪ The frequency of transport service in smart cities should not be more than 10-15 minutes
3	**Smart route connectivity**	▪ In smart cities the connectivity of routes should be key amenities as well as low income household areas also.
		▪ To develop smart integrated multimodal transport system that ensure efficient travel using multiple modes.
4	**Smart traffic management**	▪ The transport system in smart cities should be incorporated with GIS system which provides real time information of running vehicles, stops, scheduling, location of parking spaces, details of routes & alternative routes in emergency situations.
5	**Smart ticketing**	▪ The transport system provides advanced booking and payment facility, smart card and flexible & electronic ticketing system in city for users.
6	**Smart comfort**	▪ It can provide user to sufficient space of sitting and standees, comfort design & cleanliness of the seats and vehicles, real time information and integrated with various modes of public transport system.
7	**Smart safety**	▪ This aspect refers not only to safety from crimes and accidents during riding, waiting or transferring

		but also to safety related to be the behaviour of the other persons and to the transit operator.
		▪ To provide congestion free routes for safe and for rapid intervention in emergency situation of passengers and vehicles.
		▪ Safe and rapid mobility during waiting, travelling transfers and emergency situation in a city.
8	**Smart pricing**	▪ Travelling cost using a transport service in smart cities should be less than 15-20 % lesser of total income that people spent on using the transport system.
9	**Pleasant environment**	▪ No adverse impact on city environment.
		▪ To promote clean vehicle and clean fuel technologies or combination of alternate fuels.
		▪ To use the energy efficient and lower emission standard motorized vehicles.
10	**Minimum operational cost**	▪ Public transport system improves vehicle design for increase the efficient of vehicle.
		▪ Public transport system should be used to fuel alternative like biodiesel compressed and liquefied natural gases which can reduce the dependency on import the fuel.

4.3 Proposed Methodology

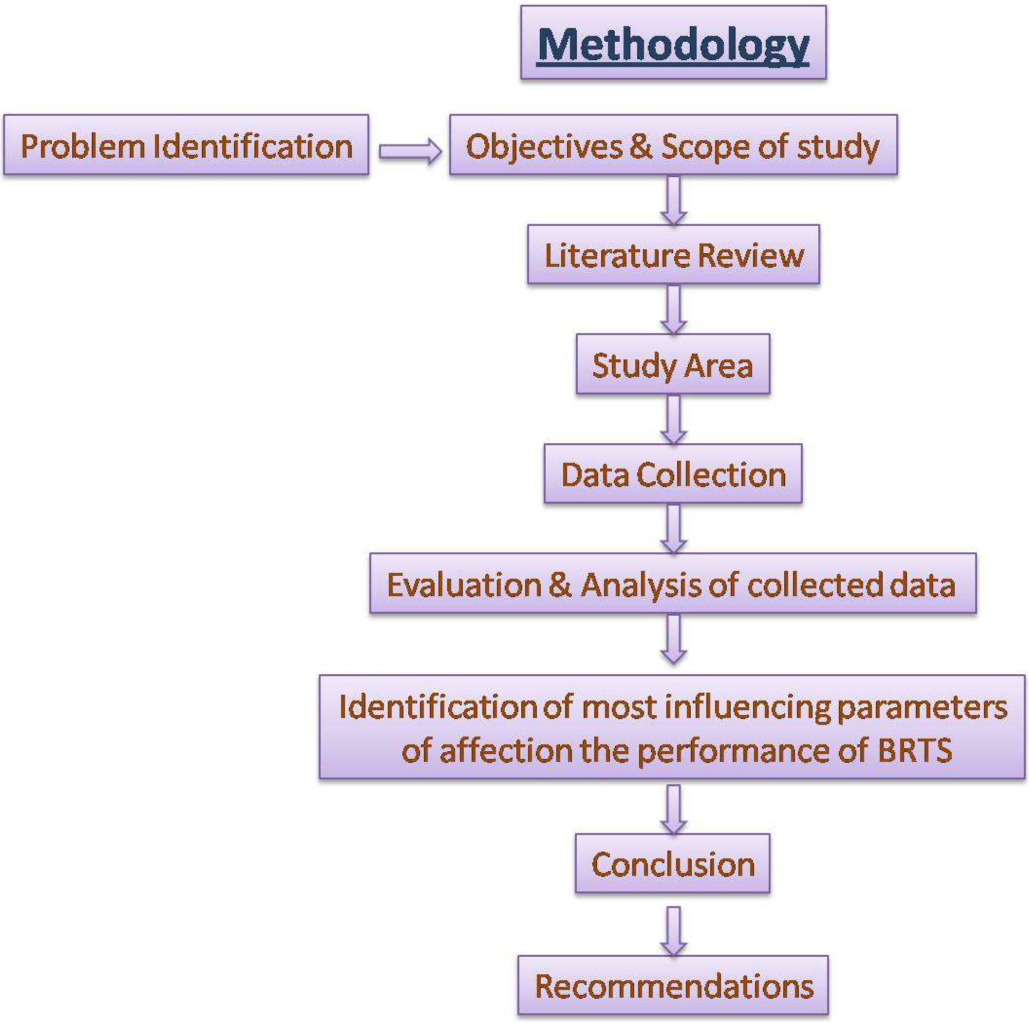


Fig.4.1 Proposed methodology flow chart

4.4 Summary

In this chapter basic requirements of ideal transportation system is discussed and proposed methodology for further work is also discussed. After this data collection and analysis is taken under consideration.

CHAPTER 5: DATA COLLECTION

5.1 General

Data collection chapter comprises of the data of surveys carried out which are (1) Travel time study, (2) People preference study, (3) Passenger frequency study, for evaluation of existing BRTS and also carried out survey for new corridor which is (4) Road inventory survey (5) classified volume count survey for Bus Rapid Transit System (BRTS) and (6) Road side interview survey.

5.2 People preference survey

In this survey is carried out Opinion of Users about BRTS. Simple survey for users of BRTS in One Questioner form. In this survey carried out 500 Questioner form users based on their experience in BRTS. In this survey take opinion from random 200 users in sample Questioner form and from survey data analysis showing below in graph.

5.3 Surveys

The different types of surveys are carried out for the data collection of BRTS like People Preference survey, Travel time survey, Delay Survey, and Passenger Movement Survey. These surveys are described below.

- People Preference Survey: - In This Survey is carried out Opinion of Users about BRTS. Simple Survey for Users of BRTS and in one Questioner Form.
- Travel Time Survey: - In this survey Travel Time study is carried out on the stretch of the BRTS between Gondal chowk to Madhapar chowk. At each station starting from Gondal chowk to Madhapar chowk there are eighteen stations.
- Delay Survey: - In this Survey Carried out Delay time during Traveling at Intersection and Station of existing BRTS corridor for predict travel time of new corridor.
- Passenger Movement Survey: In This Survey Carried out how many Passenger Alighting and Boarding from One station to next Station.
- Road inventory survey:- In this survey carried Road side detail of exciting corridor of BRTS like width of road and various part of Road mainly shoulder width,

MV lane width, Bicycle lane, Footpath, BRTS lane and also proposed corridor Dimension.

• Classified volume count:- In this survey carried out how many vehicles pass on the road in specific time for measure Peak hour and traffic volume on road.

• Road side interview:- In this survey carried how many passengers are interested to use new BRT corridor and what they think about proposing new corridor and prepared their Origin and Destination matrix.

5.4 Parameters

After performing necessary survey, required data is collected and analyzed to carry out further work. And most influence parameters were identified as mentioned below

➢ **Qualitative Parameters**

- Safety
- Comfort
- Convenience

➢ **Quantitative Parameters**

- Schedule reliability
- Service frequency
- Bus hour utilization
- Average passenger per trip
- Average travelling speed

CHAPTER 6: Data Analysis and an introduction of AHP

6.1 General

After performing necessary survey required data collected for the research work. All the data accumulated and analyzed thoroughly and then evaluated. Data was collected by question form from commuters. Received data analyzed in chart form as shown below.

Fig. 6.1 Chart on gender proportion

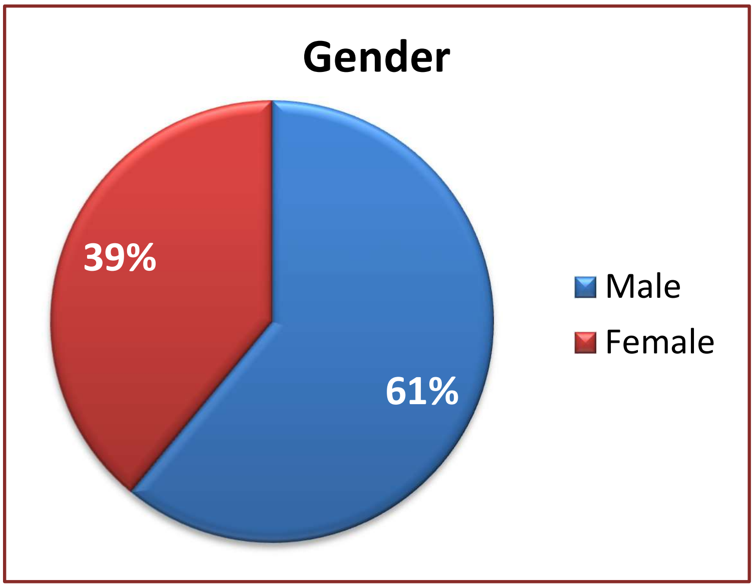


Fig. 6.2 Chart on occupation proportion

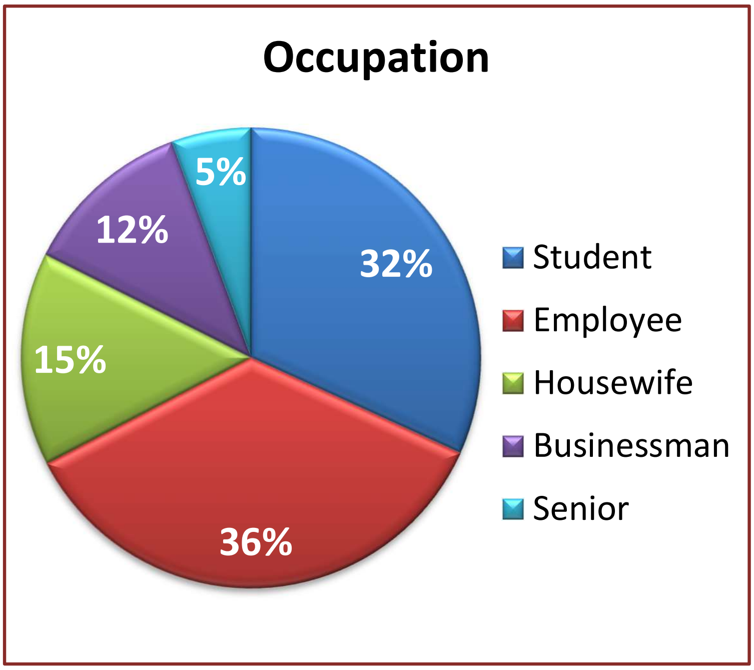


Fig. 6.3 Chart on purpose of trip

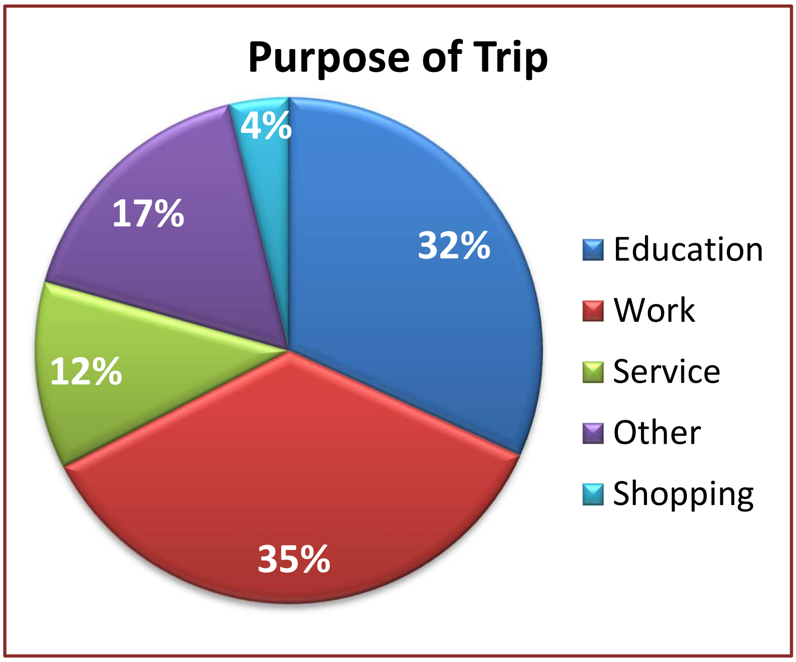


Fig. 6.4 Chart on monthly income

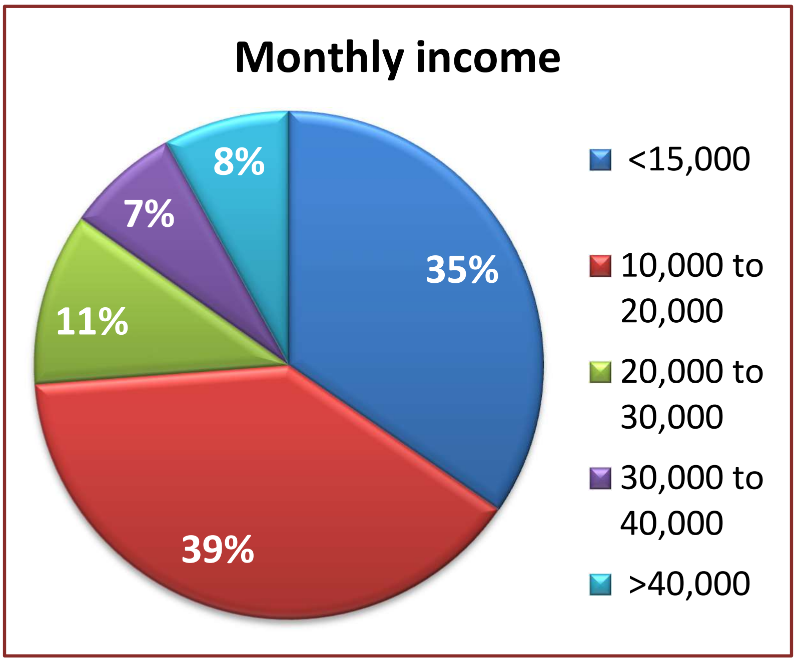


Fig. 6.5 Chart on vehicle occupancy

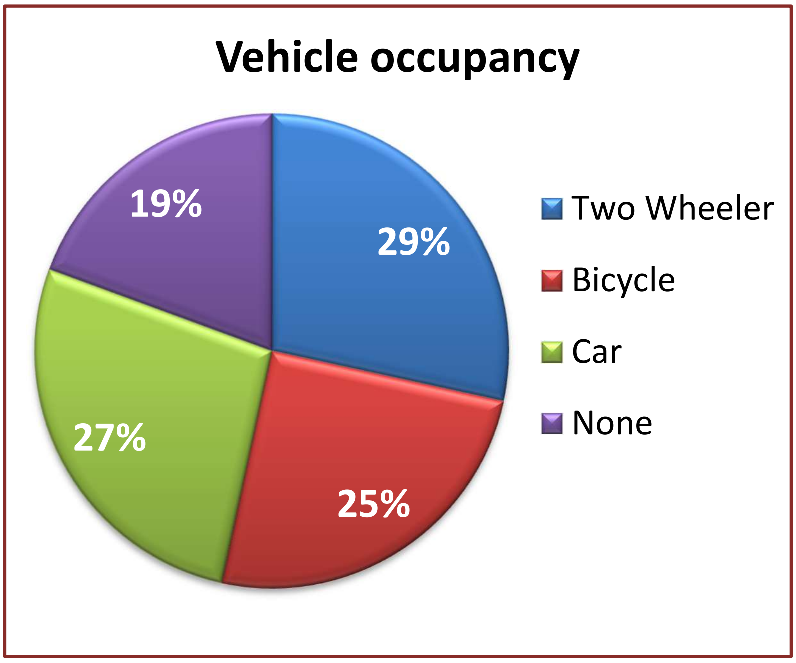


Fig. 6.6 Chart on age group proportion

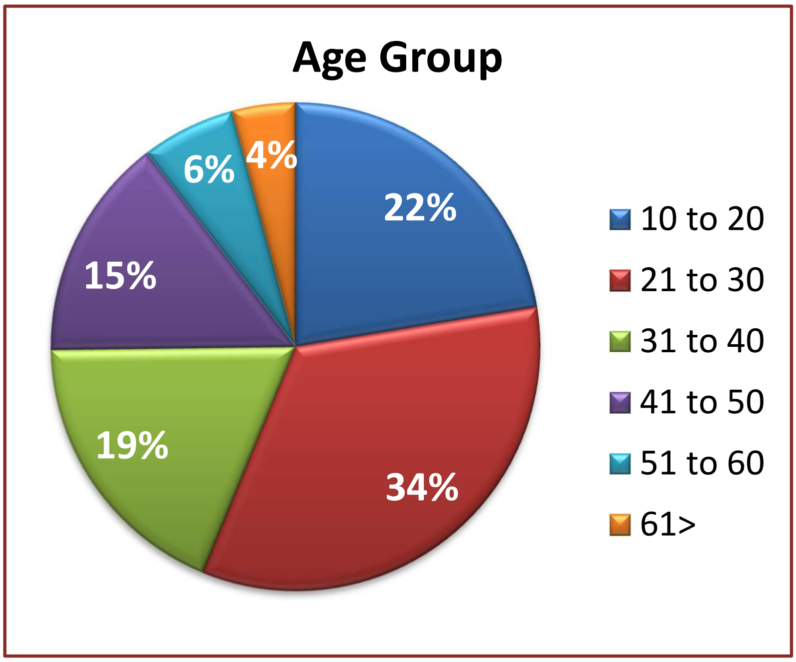


Fig. 6.7 Chart on frequent use of BRTS

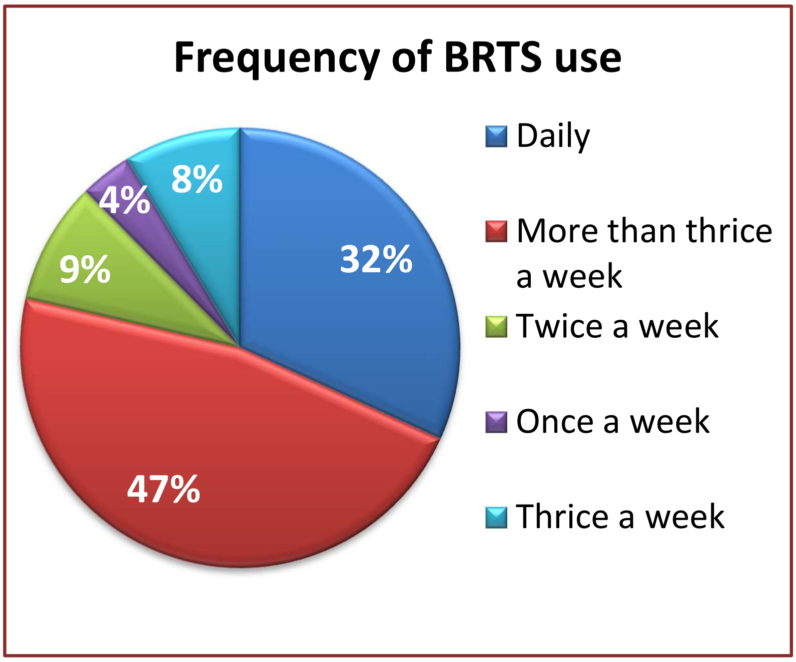


Fig. 6.8 Chart on opinion on time saving

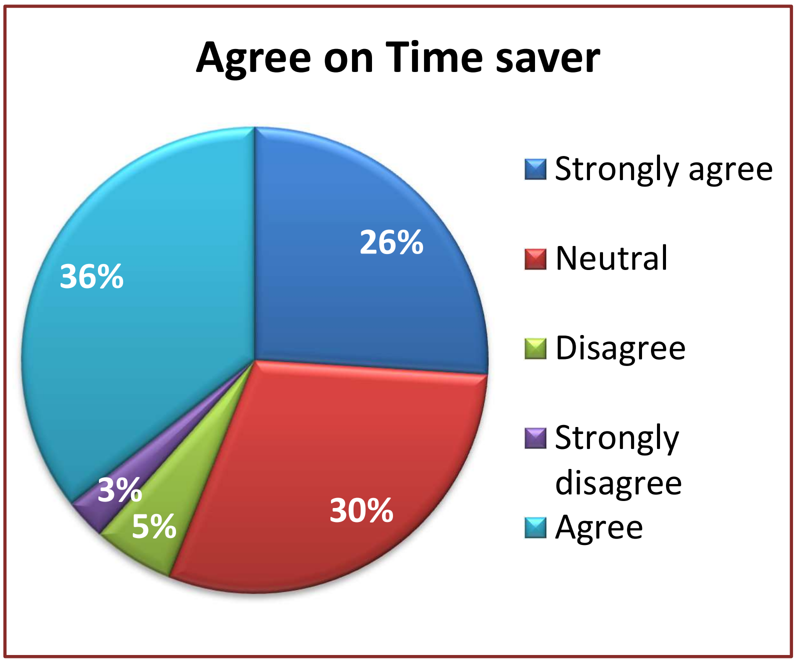


Fig. 6.9 Chart on opinion of safety

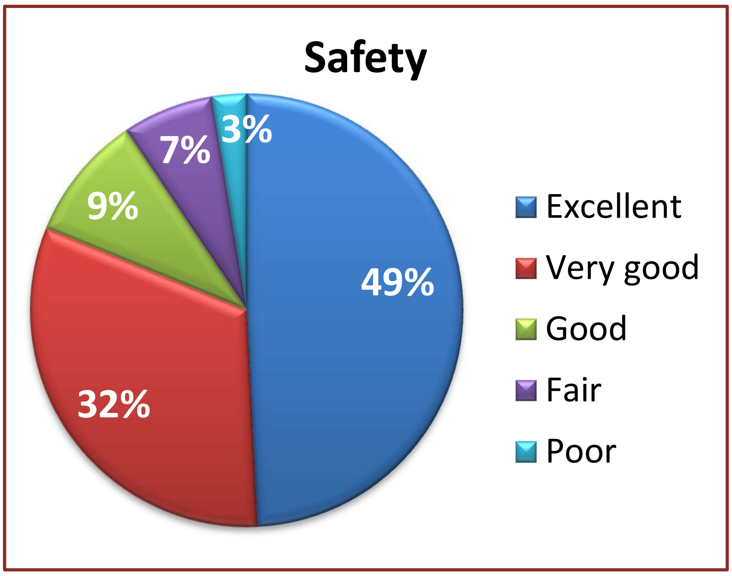


Fig. 6.10 Chart on opinion on comfort

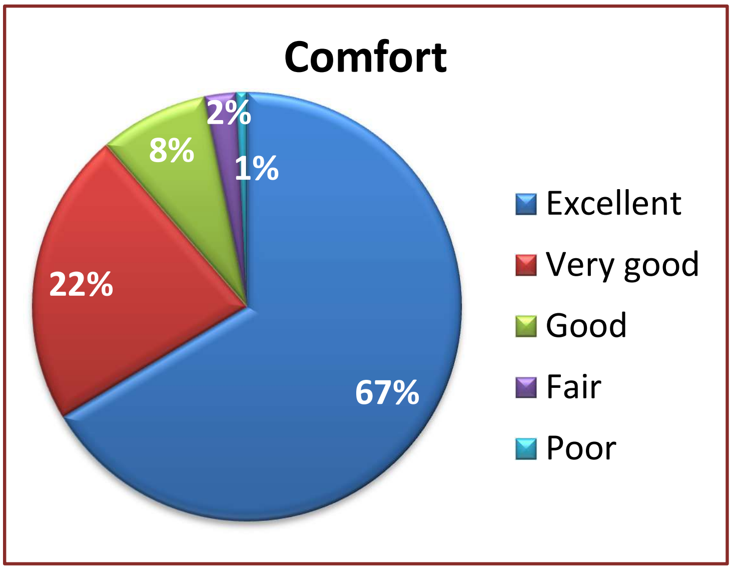
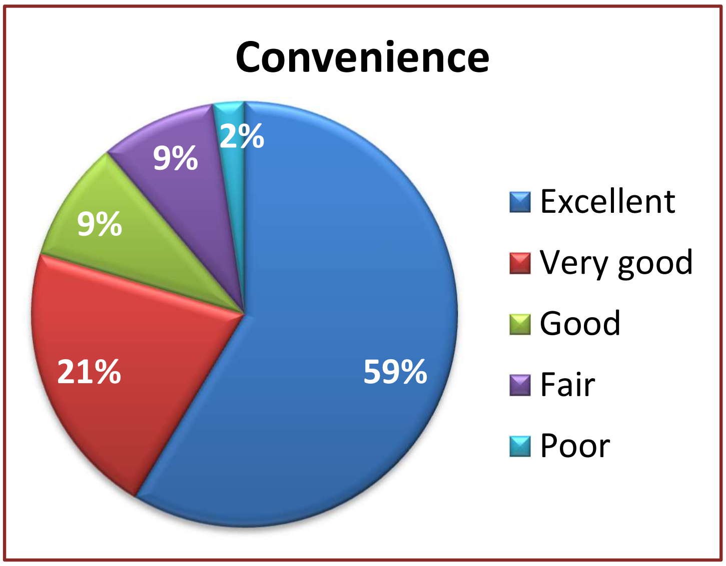


Fig. 6.11 Chart on opinion on convenience



6.2 Qualitative Analysis

In this study three qualitative criteria taken for the performance evaluation of current BRTS route.

Safety, Convenience and Comfort these parameters evaluated by the data collected from survey. Commuters were asked different questions regarding how they feel travelling by BRTS. And then data formatted and evaluated. And we directly get corresponding values for all three criteria by performing survey. The evaluated values are as shown in table below.

Table 6.1 Analysis of qualitative criteria

Sr.	Criteria	Excellent	Very Good	Good	Fair	Poor
1	Safety	246	160	47	34	13
2	Convenience	193	205	46	44	12
3	Comfort	332	111	41	12	04

Table 6.2 Evaluation of qualitative criteria

Criteria	Safety	Comfort	Convenience
BRTS route	Excellent	Excellent	Very good

6.3 An introduction of AHP

Establishing criteria for decision-making is a difficult and responsible task. In the past a single criterion optimization has usually been debated, that single criterion being – economic. Today we almost always deal with multi-criteria optimization i.e. the decision making with respect to more than one criterion. For solving those problems various mathematical methods were developed. In those methods the decision - maker has to define the structure preference for making a choice. The definition of the structure of preference is a separate problem within the multiple criteria optimization.

Psychology shows that the human brain's reaction is one - dimensional, i.e. that the brain is capable of comparing elements only two by two; that is why it is so difficult to subjectively rank lots of objects simultaneously. The problem is becoming even worse if there is more than one criterion. It is believed that humans generally are not capable of making a choice from a set that is infinite.

As a completely new approach to solving decision making problems, mathematician Saaty T (1980) developed a new method which he named the Analytic Hierarchy Process (AHP).

The AHP approach is one of the more extensively used MCDM methods. The AHP has been applied to a wide variety of decisions and the human judgment process [16]. The approach is used to construct an evaluation model and has criterion weights. It integrates different measures into a single overall score for ranking decision alternatives. Applying it usually results in simplifying a multiple criterion problem by decomposing it into a multilevel hierarchical structure. Obtaining solutions in the AHP is not a statistical procedure, because it can help either a single decision maker or a decision group to solve an MCDM problem. Description of the basic Saaty's method is given in detail bellow, together with some of its extensions and the appropriate references.

The basic characteristic:

As stated in the introduction, mathematician Tomas Saaty [22] developed, during 1980s, a completely new approach to solving decision - making problems, and named it Analytic Hierarchy Process (AHP). It is considered that the AHP method is mathematically well expounded. As a method for multiple criteria decision – making, AHP is closely related to the way an individual intuitively solves complex problems by decomposing them to more simple ones. Applying the AHP procedure involves three basic steps:

1) Decomposition, or the hierarchy construction;
2) Comparative judgments, or defining and executing data collection to obtain pairwise comparison data on elements of the hierarchical structure; and
3) Synthesis of priorities, or constructing an overall priority rating.

6.4 Quantitative Analysis:

Here in this study, five sub criteria taken for the performance evaluation of current BRTS route. This five criteria are as mentioned below:

1. ***Schedule reliability:***

   In other words this criteria is defined as on time performance or an average waiting time.

   In survey relevant data were taken for this criteria. A question was asked to commuters about the reliability on the schedule time of BRTS and how much they have to wait.

   Average waiting time= {(0*125) + (1*170) + (2*165) + (5*40) / (125+170+135+40)}

   =700/500

   =**1.4 minute**

2. ***Service frequency:***

   This criteria is defined as how frequently this service of BRTS is available for commuters. This data were taken by observation in survey.

   Average service frequency found 115

   Frequency (hr) = Frequency (Nos)/ Working hr

   = 115/16

   = **7.19 hr**

3. ***Bus hour utilization***:

   Bus hour utilization = (Total travel time*Frequency)/(No. of bus at that route*working hour)

   = (23*115) / (12*16*60)

   =**0.23**

4. ***Average passenger per trip***:

Avg. passenger/trip count = (bus seating capacity)+(no. of standing passenger at bus)

= 34+10

= **44**

Value for this = 44/34

= 1.29

5. ***Average travelling speed***:

Average travel speed (km/hour)

= Total travel distance (km) * 60 / average travel time (minute)

= (10.5*60)/23

= 27.39 km/hr.

Table 6.3 Values of quantitative criteria

Sr. No	Criteria	Value
1	Schedule reliability (min)	1.4
2	Service frequency (hr)	7.19
3	Bus hour utilization	0.23
4	Average passenger per trip	1.29
5	Average travelling speed (km/hr)	27.39

Above table represents the values of all the criteria which calculated according to data. Now this values will be compared to standardize values of AHP model then according to that criteria will be evaluated.

For the evaluation of criteria range of the various criteria is as shown below:

Table 6.4: Range of the various criteria

Criteria	Schedule reliability	Service frequency	Bus hour utilization	Avg. passenger/trip	Avg. travelling speed
Excellent	1-3	>5	1-0.80	1	>=30
Very good	3-6	3-5	0.80-0.60	1-1.5	29-25
Good	6-9	2-3	0.60-0.40	1.5-2	24-20
Fair	9-12	1-2	0.40-0.20	2-2.5	19-15
Poor	>12	0-1	<0.20	>2.5	<15

Table 6.5: Evaluation of criteria according to fulfillment

Sr. No	Criteria	Result
1	Schedule reliability	Excellent
2	Service frequency	Excellent
3	Bus hour utilization	Fair
4	Avg. passenger/trip	Very good
5	Avg. travelling speed	Very good

6.5 Design of AHP model

Case-1: Actual case

In this case AHP model will be designed as per all the data received from survey and calculated criteria. Here matrix is formed according to evaluation of criteria according to fulfillment and values taken for matrix according to fulfillment of criteria and its evaluation.

Here values taken for matrix is as below according to fulfillment:

Safety - Excellent

Comfort – Excellent

Convenience – Very good

Schedule reliability – Excellent

Service frequency – Excellent

Bus hour utilization – Fair

Avg. passenger per trip – Very good

Avg. travelling speed – Very good

Table 6.6: Pair wise comparison of criteria for Case-1

Criteria	Safety	Comfort	Convenience	Schedule reliability	Service frequency	Bus hour utilization	Avg. Passenger per trip	Avg. travelling speed
Safety	1	1	3	1	1	7	3	3
Comfort	1	1	3	1	1	7	3	3
Convenience	1/3	1/3	1	1/3	1/3	5	1	1
Schedule reliability	1	1	3	1	1	7	3	3
Service frequency	1	1	3	1	1	7	3	3
Bus hour utilization	1/7	1/7	1/5	1/7	1/7	1	1/5	1/5
Avg. Passenger per trip	1/3	1/3	1	1/3	1/3	5	1	1
Avg. travelling speed	1/3	1/3	1	1/3	1/3	5	1	1

Table 6.7 Simplification for case-1

Criteria	Safety	Comfort	Convenience	Schedule reliability	Service frequency	Bus hour utilization	Avg. Passenger per trip	Avg. travelling speed
Safety	1	1	3	1	1	7	3	3
Comfort	1	1	3	1	1	7	3	3
Convenience	0.33	0.33	1	0.33	0.33	5	1	1
Schedule reliability	1	1	3	1	1	7	3	3
Service frequency	1	1	3	1	1	7	3	3
Bus hour utilization	0.14	0.14	0.20	0.14	0.14	1	0.20	0.20
Avg. Passenger per trip	0.33	0.33	1	0.33	0.33	5	1	1
Avg. travelling speed	0.33	0.33	1	0.33	0.33	5	1	1
Total	**5.13**	**5.13**	**15.20**	**5.13**	**5.13**	**44**	**15.20**	**15.20**

Table 6.8: Normalization for case-1

Criteria	Safety	Comfort	Convenience	Schedule reliability	Service frequency	Bus hour utilization	Avg. Passenger per trip	Avg. travelling speed	Total	Average	Consistency measure
Safety	0.19	0.19	0.20	0.19	0.19	0.16	0.20	0.20	1.53	0.19	8.13
Comfort	0.19	0.19	0.20	0.19	0.19	0.16	0.20	0.20	1.53	0.19	8.13
Convenience	0.06	0.06	0.07	0.06	0.06	0.11	0.07	0.07	0.57	0.07	8.08
Schedule reliability	0.19	0.19	0.20	0.19	0.19	0.16	0.20	0.20	1.53	0.19	8.13
Service frequency	0.19	0.19	0.20	0.19	0.19	0.16	0.20	0.20	1.53	0.19	8.13
Bus hour utilization	0.03	0.03	0.01	0.03	0.03	0.02	0.01	0.01	0.17	0.02	8.00
Avg. Passenger per trip	0.06	0.06	0.07	0.06	0.06	0.11	0.07	0.07	0.57	0.07	8.08
Avg. travelling speed	0.06	0.06	0.07	0.06	0.06	0.11	0.07	0.07	0.57	0.07	8.08
total	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**8**	**1**	**64.76**

Case-2: Avg. pass/trip & Avg. travelling speed taken as Excellent

After the results of an actual case, case-2 is carried out to identify the changes by changing the criteria weightage or a value. This is not an actual scene it is just an experimental case to carry out comparison evaluation by making change in criteria.

Here values taken for matrix are as below by changing two criteria.

Safety - Excellent
Comfort – Excellent
Convenience – Very good
Schedule reliability – Excellent
Service frequency – Excellent
Bus hour utilization – Fair
Avg. passenger per trip – Excellent
Avg. travelling speed – Excellent

Table 6.9: Pair wise comparison of criteria for Case-2

Criteria	Safety	Comfort	Convenience	Schedule reliability	Service frequency	Bus hour utilization	Avg. Passenger per trip	Avg. travelling speed
Safety	1	1	3	1	1	7	1	1
Comfort	1	1	3	1	1	7	1	1
Convenience	1/3	1/3	1	1/3	1/3	5	1/3	1/3
Schedule reliability	1	1	3	1	1	7	1	1
Service frequency	1	1	3	1	1	7	1	1
Bus hour utilization	1/7	1/7	1/5	1/7	1/7	1	1/7	1/7
Avg. Passenger per trip	1	1	3	1	1	7	1	1
Avg. travelling speed	1	1	3	1	1	7	1	1

Table 6.10 Simplification for case-2

Criteria	Safety	Comfort	Convenience	Schedule reliability	Service frequency	Bus hour utilization	Avg. Passenger per trip	Avg. travelling speed
Safety	1	1	3	1	1	7	1	1
Comfort	1	1	3	1	1	7	1	1
Convenience	0.33	0.33	1	0.33	0.33	5	0.33	0.33
Schedule reliability	1	1	3	1	1	7	1	1
Service frequency	1	1	3	1	1	7	1	1
Bus hour utilization	0.14	0.14	0.20	0.14	0.14	1	0.14	0.14
Avg. Passenger per trip	1.00	1.00	3	1.00	1.00	7	1	1
Avg. travelling speed	1.00	1.00	3	1.00	1.00	7	1	1
Total	**6.47**	**6.47**	**19.20**	**6.47**	**6.47**	**48**	**6.47**	**6.47**

Table 6.11: Normalization for case-2

Criteria	Safety	Comfort	Convenience	Schedule reliability	Service frequency	Bus hour utilization	Avg. Passenger per trip	Avg. travelling speed	Total	Average	Consistency measure
Safety	0.15	0.15	0.16	0.15	0.15	0.15	0.15	0.15	1.23	0.15	8.06
Comfort	0.15	0.15	0.16	0.15	0.15	0.15	0.15	0.15	1.23	0.15	8.06
Convenience	0.05	0.05	0.05	0.05	0.05	0.10	0.05	0.05	0.46	0.06	8.03
Schedule reliability	0.15	0.15	0.16	0.15	0.15	0.15	0.15	0.15	1.23	0.15	8.06
Service frequency	0.15	0.15	0.16	0.15	0.15	0.15	0.15	0.15	1.23	0.15	8.06
Bus hour utilization	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.16	0.02	8.00
Avg. Passenger per trip	0.15	0.15	0.16	0.15	0.15	0.15	0.15	0.15	1.23	0.15	8.06
Avg. travelling speed	0.15	0.15	0.16	0.15	0.15	0.15	0.15	0.15	1.23	0.15	8.06
Total	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**8**	**1**	**64.36**

Case-3: only one criteria bus hour utilization taken as good

As we check another combination of evaluated criteria, further in this case only one criteria which identified as the lowest among the all is amplified and cheeked further.

Criteria called Bus hour utilization is taken into consideration. It came to be a 'FAIR; as a performance wise and in this case it is taken one step upward as a 'GOOD'.

Here values taken for matrix are as below by changing one criteria.

Safety - Excellent
Comfort – Excellent
Convenience – Very good
Schedule reliability – Excellent
Service frequency – Excellent
Bus hour utilization – Good
Avg. passenger per trip – Very good
Avg. travelling speed –Very good

Table 6.12: Pair wise comparison of criteria Case-3

Criteria	Safety	Comfort	Convenience	Schedule reliability	Service frequency	Bus hour utilization	Avg. Passenger per trip	Avg. travelling speed
Safety	1	1	3	1	1	5	3	3
Comfort	1	1	3	1	1	5	3	3
Convenience	1/3	1/3	1	1/3	1/3	3	1	1
Schedule reliability	1	1	3	1	1	5	3	3
Service frequency	1	1	3	1	1	5	3	3
Bus hour utilization	1/5	1/5	1/3	1/5	1/5	1	1/3	1/3
Avg. Passenger per trip	1/3	1/3	1	1/3	1/3	3	1	1
Avg. travelling speed	1/3	1/3	1	1/3	1/3	3	1	1

Table 6.13 Simplification for case-3

Criteria	Safety	Comfort	Convenience	Schedule reliability	Service frequency	Bus hour utilization	Avg. Passenger per trip	Avg. travelling speed
Safety	1	1	3	1	1	5	3	3
Comfort	1	1	3	1	1	5	3	3
Convenience	0.33	0.33	1	0.33	0.33	3	1	1
Schedule reliability	1	1	3	1	1	5	3	3
Service frequency	1	1	3	1	1	5	3	3
Bus hour utilization	0.20	0.20	0.33	0.20	0.20	1	0.33	0.33
Avg. Passenger per trip	0.33	0.33	1	0.33	0.33	3	1	1
Avg. travelling speed	0.33	0.33	1	0.33	0.33	3	1	1
Total	**5.19**	**5.19**	**15.33**	**5.19**	**5.19**	**30**	**15.33**	**15.33**

Table 6.14 Normalization for case-3

Criteria	Safety	Comfort	Convenience	Schedule reliability	Service frequency	Bus hour utilization	Avg. Passenger per trip	Avg. travelling speed	Total	Average	Consistency measure
Safety	0.19	0.19	0.20	0.19	0.19	0.17	0.20	0.20	1.52	0.19	8.07
Comfort	0.19	0.19	0.20	0.19	0.19	0.17	0.20	0.20	1.52	0.19	8.07
Convenience	0.06	0.06	0.07	0.06	0.06	0.10	0.07	0.07	0.55	0.07	8.03
Schedule reliability	0.19	0.19	0.20	0.19	0.19	0.17	0.20	0.20	1.52	0.19	8.07
Service frequency	0.19	0.19	0.20	0.19	0.19	0.17	0.20	0.20	1.52	0.19	8.07
Bus hour utilization	0.04	0.04	0.02	0.04	0.04	0.03	0.02	0.02	0.25	0.03	8.00
Avg. Passenger per trip	0.06	0.06	0.07	0.06	0.06	0.10	0.07	0.07	0.55	0.07	8.03
Avg. travelling speed	0.06	0.06	0.07	0.06	0.06	0.10	0.07	0.07	0.55	0.07	8.03
Total	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**8**	**1**	**64.39**

6.6 Calculation for the priority value:

After the making changes and values in the criteria in case-1, case-2 and case-3, matrix are calculated as shown above for respective cases. Now all the three cases is compared to each other by calculating priority values for each case. By this one can know the most and the least influenced or less effective combination of criteria.

Priority value is the value that defined the effectiveness of that particular work. Basically it is a scoring model which takes into account multiple dimensions for evaluating project work and is used to determine relative project value.

Priority values for all the three case are calculated as shown below:

Table 6.15 AHP pairwise matrix/AHP ranking

Scale	Excellent	Very Good	Good	Fair	Poor	Weights
Excellent	1	3	5	7	9	0.502
Very Good	1/3	1	3	5	7	0.26
Good	1/5	1/3	1	3	5	0.134
Fair	1/7	1/5	1/3	1	3	0.067
Poor	1/9	1/7	1/5	1/3	1	0.034

For case-1:

Priority value=

(0.19*0.502)+(0.19*0.502)+(0.07*0.26)+(0.19*0.502)+(0.19*0.502)+(0.02*0.067)+(0.07*0.26)+(0.07*0.26)

=0.09538+0.09538+0.0182+0.09538+0.09538+0.00134+0.0182+0.0182

=0.43746

For case-2:

Priority value=

(0.15*0.502)+(0.15*0.502)+(0.06*0.26)+(0.15*0.502)+(0.15*0.502)+(0.02*0.067)+(0.15*0.502)+(0.15*0.502)

=0.0753+0.0753+0.0156+0.0753+0.0753+0.00134+0.0753+0.0753

=0.46874

For case-3:

Priority value=

(0.19*0.502)+(0.19*0.502)+(0.07*0.26)+(0.19*0.502)+(0.19*0.502)+(0.03*0.134)

+(0.07*0.26)+(0.07*0.26)

=0.09538+0.09538+0.0182+0.09538+0.09538+0.00402+0.0182+0.0182

=0.44014

Table 6.16: Case wise outcome of priority value

Sr.	Description	Value
1	Case – 1	0.43746
2	Case – 2	0.46874
3	Case – 3	0.44014

6.7 Summary

Here in this chapter all the criteria are evaluated differently under three cases to know the different outcomes of their combinations. And by these evaluations one can recommend or can conclude the influence of the criteria in this study.

CHAPTER 7: RECOMMENDATIONS AND CONCLUSION

7.1 General

This chapter is main outcome or the result of the whole study and research work that has been carried out. This chapter includes the recommendations on the basis of the data analysis, calculations and evaluation of the data. Also conclusion of the whole study is given in the end.

7.2 Recommendations

In this study various parameters/criteria which are influencing and effective for the performance of the BRTS are identified, evaluated and compared in different aspects. The main aim is to check the individual as well as the multiple criteria performance and their combinations.

- After the study, this observation is carried out that by focusing on the criteria that are lesser effective needs to be consider carefully and should improve attentively.
- As mentioned in case-2, two criteria i.e. Avg. passenger per trip and Avg. travelling speed, both should improvise according to demand.
- Avg. travelling speed can be improve by the reducing delay at the intersections and Avg. passenger per trip can be improve by the considering the capacity of BRTS bus and the different demand
- As mentioned in case-3, Bus hour utilization needs to be consider as it came out to be very weak in performance among all the criteria.
- Bus hour utilization can be utilize by proper detailed study of the demand in every aspects.

Also the other recommendations which are taken during the survey, are listed below:

- Driver should be more careful
- Commuters have to follow basic discipline rules
- Seats for senior citizen should be provided
- Delay causing at intersection should be minimize
- Should provide more buses at peak hours because of heavy rush.

7.3 Conclusion

In this study, a bus route evaluation criteria for a bus transit system consisting of two major criteria and eight sub criteria are identified and an AHP model has been designed. The model has been employed to evaluate one operational route. Sensitivity analysis has been carried out to examine how sensitive the criteria's are to changes in the importance of objective. Quantitative and qualitative both criteria majorly influence the performance of current BRTS route as shown in actual case. In second case and third case as well less-influenced criteria evaluated. Its evaluation and impact and influence shown in a case-2 and case-3 on overall performance of BRTS on this route. And priority values for all three cases were calculated and changes were found accordingly.

7.4 Future scope

So by concentrating on these aspects of the study, one can get thorough understanding of criteria that influence the performance of BRTS route and by further demand analysis and improvement can shift use from the personal mode of transport toward a lot of economical and safe transport system.

7.5 Summary

This chapter includes recommendations, conclusion and future scope of the study. Recommendations given according to problem statement and research work carried out according to current performance. Conclusion of the study is also given in this chapter. And also some future scope of the study is given so that one can refer this study and carry out research work for improvement and the betterment of the existing system.

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LRT- Light Rail Transit

SPV- Special Purpose Vehicle

CBD- Central Business District

NMT- Non-Motorized traffic

ITDP- Institutes for Transport Development and policy

AVL- Automatic Vehicle Location

GPS- Global Positioning System

RTO- Regional Transport Office

RMC- Rajkot Municipal Corporation

GSRTC- Gujrat State Road Transport Corporation

NH- National Highway

SH- State Highway

NUTP- National Urban Transport Policy

RRL- Rajkot Rajpath Limited.

CVC- Classified Volume Count

PCU- Passenger Car Unit

HCV- High Commercial Vehicle

LCV- Light Commercial VehicleBibliography

Annexure I

Questionnaire Form

Name : ______________________________________ Date : _______________

Gander: Male/ Female Occupation: _________________ Origin : _______________

Destination : _________________________ Purpose of Trip: ________________

House hold monthly income	✓ ⊗
<15,000	
10,000 to 20,000	
20,000 to 30,000	
30,000 to 40,000	
>40,000	

Vehicle occupancy detail:			
A	Bicycle	**B**	Two Wheeler
C	Car	**D**	None

Age Group	
10-20	
20-30	
30-40	
40-50	
50-60	
60-70	

1. How often you use BRTS?

A) Daily B) Once a week

C) Twice a week D) Thrice a week E) More than thrice a week

2. Is travelling by BRTS saving time?

A) Strongly agree B) Agree C) Neutral

D) Disagree E)strongly disagree

3. Do you feel safe by travelling in BRTS?

A) Excellent B) Very good C) Good

D) Fair E) Poor

4. If there is an emergency, will you use BRTS?

A) Yes B) No C) Not sure

5. How much you have to wait?

A) 0 minutes B) 0-1 minuet

C) 1-2 minutes D) 2-5 minutes

6. Are you satisfied with BRTS busses?

A) Satisfied B) Somewhat satisfied

C) Dissatisfied D) somewhat dissatisfied

7. Is it easier to reach BRTS bus stop boarding in bus?

A) Excellent B) Very good C) Good

D) Fair E) Poor

8. How do you feel about travelling by BRTS?

A) Excellent B) Very good C) Good

D) Fair E) Poor

9. How do you rate BRTS service?

A) 1 Star B) 2 Stars C) 3 Stars

D) 4 Stars E) 5 Stars

10. Which factor of BRTS attracts you the most?

A) A/c Volvo bus B) Time punctuality

C) Platform level boarding D) Less Crowd

11. Give your suggestion, if any:

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

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Annexure II

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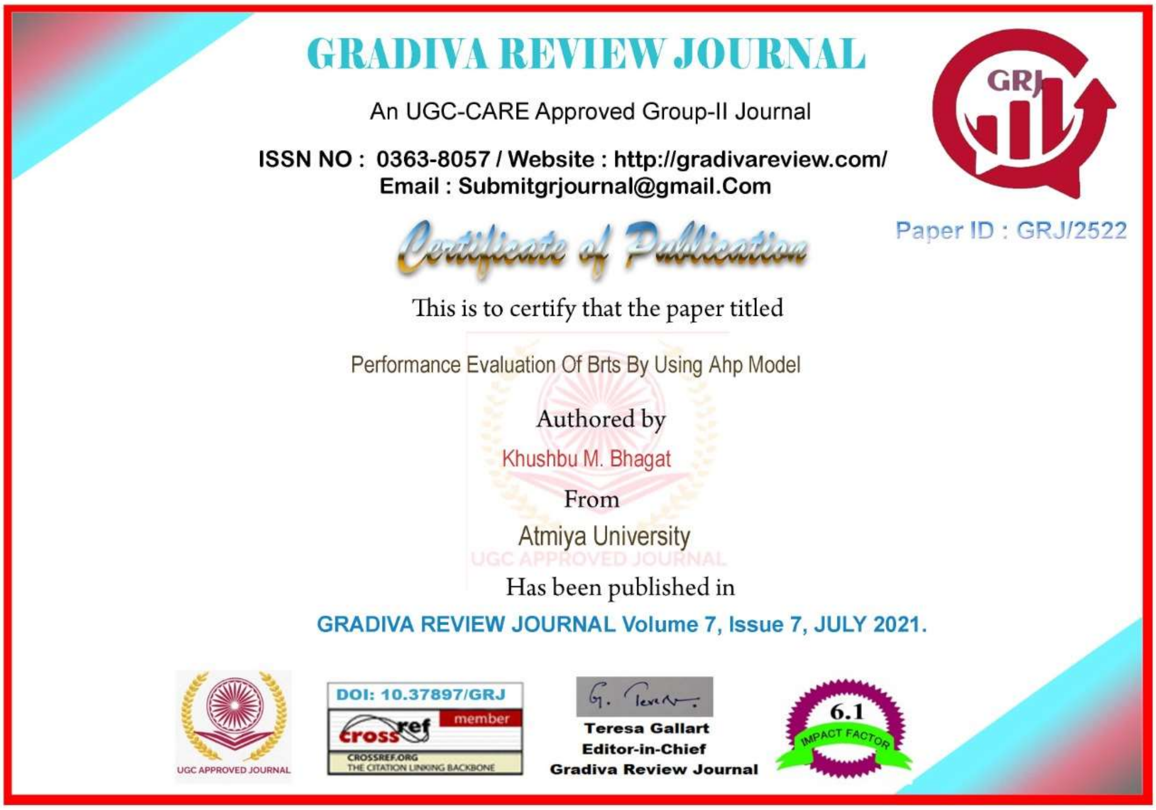
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6.1 IMPACT FACTOR

Annexure III

PLAGIARISM CERTIFICATE

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