ANALYSIS AND PERFORMANCE EVALUATION OF BUS RAPID TRANSIT (BRT) MULTAN

By

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Department of Transportation Engineering

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National University of Sciences and Technology

Islamabad, Pakistan

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A thesis submitted to the in partial fulfillment of the requirements for the degree

of

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in

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Thesis Supervisor: Dr. Sameer-ud-Din (P.E.)

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THESIS ACCEPTANCE CERTIFICATE

It is certified that final copy of MS Thesis written by Mr. Syed Muhammad Wajahat Noor

(Registration No. 00000275007), School of Civil and Environmental Engineering has been vetted by undersigned, found complete in all respects as per NUST Statutes/ Regulations/ MS Policy, is free of plagiarism, errors, and mistakes and is accepted as partial fulfillment for award of MS degree. It is further certified that necessary amendments as point out by GEC members and foreign/ local evaluators of the scholar have also been incorporated in the said thesis.

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Date: _____

Signature (HOD): _____

Date: _____

Signature (Dean/ Principal) _____

Date: _____

FORM TH-4

CERTIFICATE OF APPROVAL

This is to certify that the research work presented in this thesis, entitled "Analysis and Performance Evaluation of Bus Rapid Transit (BRT) Multan: "Increasing the Ridership of BRT Multan" was conducted by Mr. Syed Muhammad Wajahat Noor Bukhari under the supervision of Dr. Sameer-ud-Din (P.E.).

No part of this thesis has been submitted anywhere else for any other degree. This thesis is submitted to the Department of Transportation Engineering (TN) in partial fulfillment of the requirements for the degree of Master of Science in field of Transportation Engineering, National University of Sciences & Technology (NUST) Islamabad, Pakistan.

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I Syed Muhammad Wajahat Noor Bukhari hereby state that my MS thesis titled Analysis and Performance Evaluation of Bus Rapid Transit (BRT) Multan is my own work and has not been submitted previously by me for taking any degree from this University National University of Sciences & Technology (NUST) Islamabad, Pakistan or anywhere else in the country/ world.

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DEDICATION

I would like to dedicate my thesis to my beloved parents, teachers, siblings and fellow students of the National University of Science Technology.

ACKNOWLEDGEMENT

I am extremely thankful to Allah Almighty, for giving me strength and patience to complete this research project. A little effort though but inspired by the Verse from The Holy Quran:

"And whoever saves a life is as though he had saved all mankind". **(5: 32)**

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Thank You All!

Syed Muhammad Wajahat Noor Bukhari

ABSTRACT

A Bus Rapid Transit (BRT) turns out to be a cost-effective and user efficient transportation system. Especially, in urban areas where it provides safe and high-quality transport services throughout the world. The BRT system was introduced, the first time in Lahore Pakistan followed by a chain of BRTs in Rawalpindi, Multan and Peshawar BRT. This proposed research study focuses upon performance elements like safety, productivity, user perception, utilization and qualitative aspects of level of service for BRT Multan, which are the prominent contributing factors in success of any mass transit system. To analyze and evaluate the performance and quality aspects, the data collected from 21 BRT stations through surveys and interviews is statistically analyzed. This study concluded important results based on the user comfort adaptation and presents a critical overview to enhance the mobility of citizens within the existing BRT system providing a benchmark to transport planners and policy makers.

Keywords: Bus Rapid Transit, User Perception, Performance Evaluation, BRT Multan, Quality Aspects.

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LIST OF ABBREVIATIONS

CPEC	China Pak Economic Corridor
BRT	Bus Rapid Transit
IOT	Institute of Transportation
JICA	Japan International Transportation Agency
ITDP	Institute of Transportation and Development Policy
PMA	Punjab Mass Transit Authority
ITS	Intelligence Transportation System
HSRS	High-speed Railway System

CHAPTER 1: INTRODUCTION

The development of any country largely depends upon the public transport system, especially in urban areas [1]. The transportation system in urban areas acts as the backbone for development and economic growth because it improves the accessibility and mobility. It increases the business activities as a result of the connection between commercial hubs with the central part of a city, bridged by the transportation system [2]. Therefore, public transportation plays important role in providing convenient, safe, and economical journeys to all the users of that facility. The public transport systems are therefore continuously improved and evolved globally, with the passage of time in order to keep up with the sustainable goals in urban areas which improves the national economy [3]. A similar improvement was adopted in Pakistan in terms of BRT services, one of these BRT systems has been provided for the citizens of Multan. In this proposed research project, the BRT Multan will be investigated in order to evaluate its performance, efficiency, and affordability [4].

The travel time and level of service are among the important parts of urban cities, which had faced numerous challenges over the last couple of decades due to urbanization and globalization. To keep the desired growing rate of the national economy, the improvement in the transportation system as part of the demand management technique should be the ultimate goal for public sector policymakers [5]. The travel time has been affected adversely by the adaptation of "Predict and Provide" model which encourages the private modes of communication resulting in abrupt increase in congestion. Likewise, in Pakistan (like other developing countries), the people choose private mode over public mode of transportation because of the travel

time, unsafe and less convenient trips provided by the public transport. Currently, the government of Pakistan is putting a lot of effort to provide sustainable trips to commuters. Various Federal and Provincial development schemes have been initiated by the respective governments i.e., China Pakistan Economic Corridor (CPEC), Metro mass transit schemes such as BRTs in urban areas. A bus rapid transit (BRT) system was started under the priority of the Punjab government in Multan [6].

Multan is one of the largest city of Pakistan with the population is about 2.2 million people and has occupied an area of 133km2, this city has gained a reputation as industrial, commercial, and with the rich cultural heritage of Pakistan. This city has been recognized as the oldest city of Asia which has been under evaluation throughout history for the development of urban infrastructure [7]. Now the customers are more inclined towards making a rational decision about utilities. The primary aim of this research paper demonstrates several important aspects for maintaining passenger utilities and the impact of their behavior on new transit projects. The city of Multan has a vast transportation network, the city mostly has narrow streets and few motorways, the city is dominated by motorcycles and qingqui rikshaws. Only 17% of people are using cars as a mode of transportation, while thousands of three-wheelers are functional without any official motorized rule. The local authorities are more inclined towards developing mass transit modes with more speed and efficiency to cater to travel needs [8].

BRT have supported the city transportation system with promoting sustainability, as they are following the Lahore BRT project example initiated in 2013 (Lahore Transport Company) which introduced Punjab Metrobus Authority in 2011. These are sustainable efforts to understand travel trends and preferences in Multan city

and make it an essential part of future travel patterns. The studies explore the various corridors of mass transit in Multan city for evaluation according to the travel needs of passengers traveling through various routes [9]. The main area of focus is to calculate the waiting period, check-in, check-outs by passengers in MFR (Multan Feeder Route) and MMBS (Multan Metro Bus Service). Multan Metro bus system has 21 stations along with the entire route plan, it is 18. kilometers longs and with elevated 12 km sections, it has 14 elevated stations and 7 at-grade stations [10].

The city people have massive inter-city and intra-city movements via different modes of transportation. The network of road in the Multan was very overburdened and congested due to which the residents of Multan's city were facing many problems i.e., accidents, economic losses, congestion and most importantly environmental degradation. The Punjab Government planned to launch Multan BRT in January 2017 to address these mounting issues. [11].

The BRT Multan route expands over a total length of about 18.5 km with 21 stations. The average of the distance between stations is around 880m. The BRT route is separated physically with the help of a fence from the regular roadway. The BRT Multan operates between 6:15 am to 10:00 pm, seven days a week, providing community services to the city residents. An additional 13 feeder lines have also been recently added as proposed by the Punjab Mass transit Authority. These feeder lines support the BRT Multan in operation and physical integration [9]. A complete aerial view of the BRT route is presented in Figure 1-1 below.

The word transportation system has been revolutionized with digitalization and technological progress, cloud computing and IoT have developed the ways to commute within the countries and locally. Global transportation sustainability is highly correlated

with green technologies and zero carbon emission projects. Therefore, this research will evaluate Bus Rapid Transit Service by finding reasons for less ridership of BRT and quality aspects of the transport system. The elements include service planning, infrastructure, stations, communications, access and integration, and other elements like alternate modes. To get data regarding these elements, extensive visits will be required to the BRT corridor

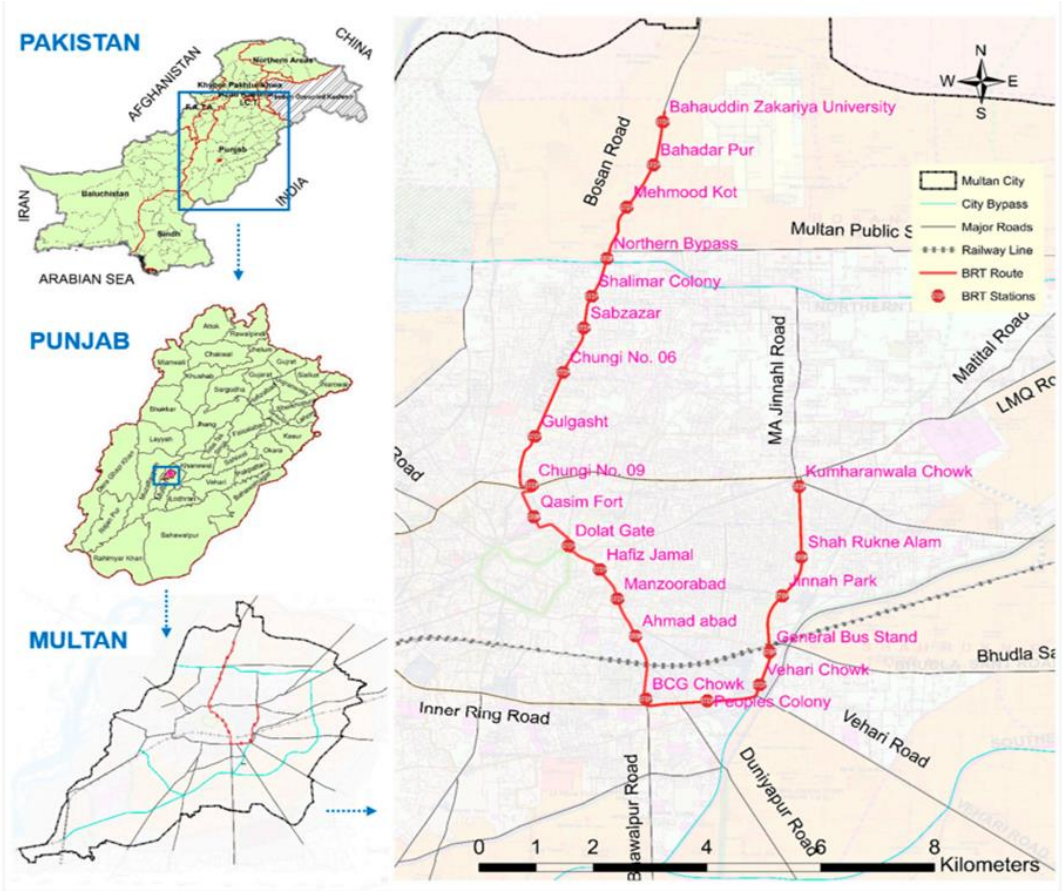

Figure 1-1: BRT Multan Route Layout (Source: PMA)

The research will be helpful to evaluate BRT Multan by surveying various elements. It will determine the modal shifts based on various variables involved. The model will be generated based on various variables. The model will help to determine the modal shifts towards BRT. The derived results will help us to lower the congestion on the routes by making suitable policies. The research study will be helpful to the

government and operating agency which will evaluate the different elements of BRT Multan. The study will analyze the BRT service planning, infrastructure, stations, communication, access and integration and other elements of BRT Multan. It will help the government/operating agency to find spots where to work to improve the services of BRT Multan.

At present BRT multan has been going through very less ridership. The claimed ridership was 95000/day while we are just be able to achieve 25000-35000/day. In this study we have done the performance analysis which would reveal the reason of less ridership in BRT Multan. 86% commuters don't prefer BRT Multan as a mode of travelling due to high travel time.Current ridership is not even equal to 50% of the expected ridership. The model will be generated which will help relevant agencies to find the modal shifts of commuters.

The application of the research study is not limited only to BRT Multan but the same study can be applied to other BRTs operating or under construction in various cities. The study can be applied to any BRT to evaluate them and to find the spots where improvement is needed to enhance the services of BRT. The same study can be applied but with little bit changes in factors and variables to be considered.

1.1 Problem Statement

Although the government has initiated the development and BRT Multan was built to share the burden of the congested routes, apparently, the main cause of congestion on the road network is due to many reasons, including: lack integration with the other modes of transportation, increase in vehicles over the road network, irregular non scheduled feeder routes services, higher occupancy of BRT buses due to running less number of buses.

1.2 Study Objectives

In order to answer the above question, we have set main objectives as follows.

- Evaluating the current BRT existing data including: features, demand, ridership, waiting time, number of stops, bus fare, etc.
- Figure out the gaps in the existing services and subsequently proposing intervention to address current challenges, and
- Evaluating in basis of performance, generalized cost, and reduction in travel time and fare costs.

1.3 Scope and Research Area of Study

The Multan Metrobus was built in January 2017, at the cost of 29 billion Pkr. The BRT route start at BZU (Bahaudin Zakariya University) in northern Multan and heads southward to pass by the east of Multan's old city at the Daulat Gate before turning and finally terminate at the Kumharanwala Chowk in eastern Multan.

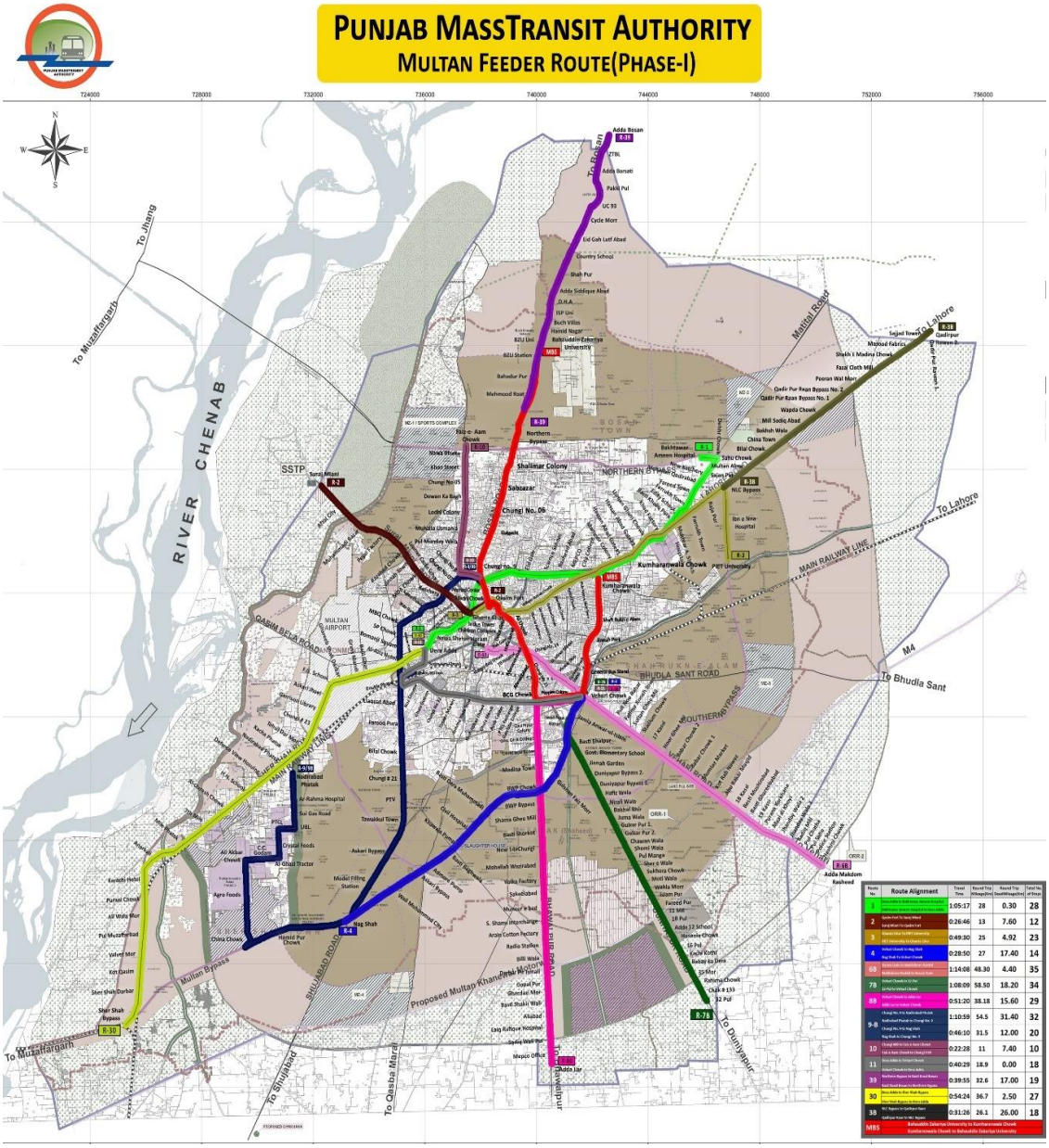

Figure 1-2 : Feeder Bus Service Route(Source:PMA)

The BRT route serves 21 stations over the course of 18.5 kilometres, of which 12.5 kilometres are elevated, 14 stations are elevated, while the remainder are at grade. The route menure through the residential and commercial areas. Their Characterstics has been explained the the Table 1-1 below

Table 1-1: Characteristics of Stations

S/No.	Station	Characteristics
1	Bahauddin Zakarya University	Surrounded by Bahaudin Zakariya University and Residential Area
2	Bahadarpur	Surrounded by Residential Area
3	Mehmood Kot	Surrounded by Residential Area
4	Nothern Bypass	Junction of different roads
5	Shalimar Colony	Surrounded by Residential Area
6	Sabzazar	Surrounded by Residential Area
7	Chungi No. 6	Surrounded by Residential Area & Commercial Area
8	Gulgasht	Surrounded by Residential Area
9	Chungi No. 9	Surrounded by Residential Area & Commercial Area
10	Qasim Fort	Surrounded by Residential Area
11	Dolat Gate	Surrounded by Residential Area
12	Hafiz Jamal	Surrounded by Residential Area
13	Manzoorabad	Surrounded by Residential Area
14	Ahmedabad	Surrounded by Residential Area
15	BCG Chowk	Surrounded by Residential Area
16	Peoples Colony	Surrounded by Residential Area
17	Vehari Chowk	Junction of different roads and General Bus stand
18	General Bus Statnd	General Bus stand
19	Jinnah Park	Surrounded by Residential Area
20	Shah Rukn-e-Alam	Surrounded by Residential Area
21	Kumharan Wala Chowk	Surrounded by Residential Area

BRT Multan has been feed by 13 routes. Each route has different number of stops, travel time as well as rounds each day which are explained in the Table 1-2 below

Table 1-2: Details of Feeder routes of Multan

Route No.	Route Alignment	Travel Time	Round Trip Mileage (Km)	Round Trip Dead Mileage (Km)	Total No. of Stops
1	Dera Adda to Bakhtawar Ameen Hospital	1:05:17	28	0.3	28
2	Qasim Fort To Suraj Miani	0:26:46	13	7.6	12
3	Ghanta Ghar To PIET University	0:49:30	25	4.92	23
4	Vehari Chowk To Nag Shah	0:28:50	27	17.4	14
6B	Haram Gate to Makhdoom Rashid	1:14:08	48.3	4.4	35
7B	Vehari Chowk to 32-Pul	1:08:09	58.5	18.2	34
8B	Vehari Chowk to Adda Lar	0:51:20	38.18	15.6	29
9B	Nadirabad Phatak to Chungi No. 9	1:10:59	54.5	31.4	32
9B	Chungi No. 9 to Nag Shah	0:46:10	31.5	12	20
10	Faiz e Aam Chowk to Chungi #09	0:22:28	11	7.4	10
11	Dera Adda to Vehari Chowk	0:40:29	18.9	0	18
39	Northern Bypass to Basti Band Bosan	0:39:55	32.6	17	19
30	Dera Adda to Sher Shah Bypass	0:54:24	36.7	2.5	27
3B	NLC Bypass to Qadirpur Raan	0:31:26	26.1	26	18

CHAPTER 2: LITERATURE REVIEW

The public transportations systems are very important in development of a country, especially in the developing countries where inadequate public transport system leads to several environmental and socio-economic issues such as social exclusion, traffic congestion and environmental degradation [12]. Therefore, the life quality, social inclusion and health care must be considered and prioritized while planning public transportation projects which will also reduce the use of private vehicles which results in increase mobility and less congestion [13]. The bus rapid system is commonly adopted in order to cater for sustainable mobility, reduce congestion and environmental impacts.

2.1 Bus Rapid Transit System

Bus rapid systems offers speed, high service quality and high capacity at a much lower relative cost than other public transport systems. Thus, fulfilling all the desired goals of an efficient and reliable public transport system and is best fit rapidly growing solution for public transportation in most of the developing countries [14]. In other terms, BRT may be described as a flexible rapid transit system with rubber tyres. It creates an integrated transportation system with integrity and a good reputation by fusing cars, services, stations, and ITS (intelligent transportation system). [15]. In general BRT system combines and integrate segregated bus lanes (typically median aligned) with off-board fare collection, Bus priority at junctions/intersection, level boarding and other such quality elements into a single public transport system.

For attracting users, several operational and physical features can influence the performance of BRT, including significant elements of BRT such as stations, fare collection, vehicles, running way, services, intelligent transport system, operating plans , branding and integration into BRT. The performance of BRT system greatly influence the decision making of its users [16]. Utility theory has significance for choosing modes of transportation, choices to made from transit and auto. A traveler considers various factors before selecting any specific mode of transport, that functions as a generalized approach. The traveller consumers do not focus on maximizing the utility rather their main perspective is to consider the generalized cost. Disutility is an important element for transit passengers' behaviour, Transit services analysis is based on waiting time, transfer time, fares, and egress time. The valuable conclusion for passenger behaviour studies is based on passenger waiting time concerning transfer time that is interpreted with in-vehicle times. Most of the previous studies predict the transfer time to be heavy on passengers rather than the waiting time.

2.2 BRT'S Evaluation in Pakistan

Farhan et al evaluated Rawalpindi-Islamabad BRT on basis of BRT Standards 2016 and compared various elements of BRT Rawalpindi-Islamabad with international BRT standards 2016. They also evaluated the performance of BRT Rawalpindi-Islamabad. Rawalpindi-Islamabad achieved the bronze BRT criteria. It has evaluated that Rawalpindi-Islamabad BRT does not fulfil the criteria of infrastructure, service planning and integration and access [17]

Multan metro bus had started with 47 buses with the estimate of 90,000 passegers/day However, the service was not be able to meet the target as prescribed.

After facing losses, 10 buses were sent to the Lahore BRT project. Although, the 37 buses were even not be able to attain the passengers Target. To prevent the service from losses, 19 buses were parked and reduced the number to 18 buses. Furthermore, 100 feeder bus services were launched in the inital phase to feed passengers to the 18 buses to improve the accessibility. Later, 100 more buses were taken to improve the facility and number reached to 200 buses by accommodating possible routes in Multan. Afterwards,Feeder buses were reduced from 200 to 115 bus due to lack of public interest.

Rathore and Ali evaluated Lahore Bus Rapid Transit on basis of 2014 BRT Standards and compared various elements of BRT Lahore with international standards of BRT 2014 to evaluate the performance of BRT Lahore. Lahore BRT failed to achieve Gold, Bronze and Silver and achieved Basic BRT level. They also evaluated those deviations from transport policies and studies conducted by JICA lead to failure of the transport system in Lahore and found out that the Lahore BRT is facing operational and maintenance problems [18].

Hafiz Usman and Abdul Azeem did performance evaluation of metro bus Lahore which is 27km long corridor with 27 stations and the average daily ridership of 125,000. Performance evaluation was assessed based on productivity, service frequency, product capacity, safety, utilization and service provided. Information was collected from different surveys, interviews and metro bus authority to evaluate the performance of metro bus Lahore. They analyzed headway, accidents, frequency, passenger boarding, reliability, transit availability, Transit quality to assess the performance of Metro Lahore. They evaluated that the metro bus service is satisfactory in all respects including safety, quality, security and of good reliability [19]

Panchore et al, 2016 evaluated BRT as a faster mode of mass transportation than other available modes with 50kph or more average operating speed. According to him, the exclusive right of way is required for rapid transit. Rapid transit is faster mode as compared to those sharing roads. BRT is a rapid transit mode with high flexibility and performance and it combines different system, operating and physical elements into an integrated system that provides high quality and reliable service. BRT is lower cost and high-capacity service that can increase mobility [20].

Seraj et al 2015 did analysis of commuter preferences to proposed bus rapid transit system in Dhaka. They studied the distribution of respondents for existing modes by gender, age, monthly income and occupation. About 69% of respondents were male, 11.25% of respondents were of more than 45 years ago, 44.73% of respondents were between 30-45 years ago, 44.01% of respondents were between 14-30 years ago. 18.45% of respondents were of business class, 57.16% were job holders and 24.39% were students. They developed logit models to find the commuter preferences between the existing modes and the proposed Bus Rapid Transit by finding utility of modes. They surveyed people in the form of questionnaires to get real-time data and asked about their preferences about the hypothetical scenario. They used a binary logit model for commuter choices between existing and proposed mode. Separate models were generated for bus, car, CNG runs auto-rickshaw, rickshaw with BRT that predict the modal shifts between existing and proposed BRT mode [21].

Fatima et al, 2014 performed a study to determine modal shifts from private users to proposed BRT in Surat, India. The municipal area of Surat is 312 sq km having a population of 2.4 million according to 2001 census. Seven corridors were proposed and one of them was selected for a study known as Dumas's resort canal- road having a length of 23.5km. A combination of stated preference and revealed preference survey

of 1250 commuters was conducted to determine traveller's present preferences and future preferences to shift towards BRT. Binary logit analysis was adopted to determine the utility functions for model generation. SPSS and Biogeme procedures were used to estimate the models. Five modes were selected for analysis namely car, shared auto, two-wheeler, bicycle and local bus. t-statistic for constant and all attributes was more than 1.96 which indicates good results. SPSS shows a shift of 37.38% and Biogeme shows a shift of 45.46% from two-wheelers towards BRT. Shifts from shared autos towards BRT was estimated to be 87.40% and 80.58% for Biogeme and SPSS models respectively. Shifts from cars towards BRT was calculated as 11.49% and 6.78% for Biogeme and SPSS models respectively. Shifts of Bus towards BRT were calculated as 85.16% and 71.99% for Biogeme and SPSS models respectively. Shifts for bicycles towards BRT were calculated as 64.91% and 55.87% for Biogeme and SPSS models respectively. SPSS analysis shows that 42.1% of the commuters are going to shift towards BRT while Biogeme analysis shows that 49.07% of the commuters are going to shift towards BRT. The study also revealed that users of SMC bus and shared autos have shown the willingness of 78.575% and 84% towards BRT [22].

2.3 Evaluation Based on User Perception

The Corridors-based analysis demonstrates the demand elasticity which generalist cost perspective which can be determined within the valid reasons according to the study area. The demand elasticity helps to predict the modification in travel habits that has been studied with extending factors of evaluation [23]. The least regression method has been used to present the two stages of regression analysis, the known transportation variables such as Population Geography and economic condition are considered with transport variables known as fuel prices transit supply, and cost. Many

other studies have observed consistent research as a transit supply is positively and fairs are negatively correlated as being significant predictors of transit ridership [24].

The current situation of travel disutility is computed through the generalized cost method which is further elaborated with the Express service launch. The standard plasticity models define the correlation of this utility of the changes in writership trends [25]. The elasticity had short term and long-term impacts on the findings with the involvement of various input units, locations, and modes. Holmgren 2007 believes in the utilization of the meta-analysis method to draw valuable conditions about the significance of functional data forms and various environmental factors that are protected in these elasticates [26].

2.4 Evaluation Based on BRT Service Utilization

The BRT system provides the foundation for future strategic planning and execution of route mapping within the local travel line. BRT performance indicators are based on various stages of planning, designing, and various aspects of user satisfaction. The user satisfaction level is a critical assessment factor for regular monitoring and to bring improvement of the system, previous studies have provided user perception surveys [27]

Some previous findings have demonstrated the service quality of the Public Transportation system while using the source methodology impact. Acura et al, status about an evaluation method of service quality with high-speed railway system in Turkey (HSRS) it has been represented with a detailed evaluation to measure the quality service concerning passenger perception in 7 different dimensions: fare, accessibility

level, passenger information, station environment, vehicle environment, security, and Service Delivery System [29].

A similar study was performed in Italy in the Metropolitan area of Cagliari, this study was focused on discovering urban transport management while considering the consumer perspective with high-quality public transport facilities. Research work took the ten attributes to analyze the service quality of the Public Transportation system. These attributes were service reliability, route characteristics, drivers' behavior, drivers' ability to maintain safety, onboard security and comfort, proximity to bus stops, boarding, and delegating ease. This research work was infrared by structural problems in lack of sustainability while measuring the perception of quality [30]. Khalid et al. states the challenges faced in the twelfth country urban environment bus and transit service system [31].

Pakistan has gone through several economic and political challenges during the recent decade which has increased the hurdles for a common person. Singers open face challenges regarding their expectations, about desired quality of services. Private vehicle owners don't feel attracted towards using the public transport service due to the less efficient system and the overwhelming situation inside the buses. Quantified user perception collected from the rail transports of Malaysia a structured survey was conducted. According to the international standards the BRT scorecards are provided by the transportation development and policy (ITDP) their authority as well what's the corridor according to international standards. The standard is incorporated with the planning and operational standards of the BRT corridor categorized as gold silver and bronze category while scoring [17].

Therefore, it is of paramount importance to evaluate the quality of the BRT corridor according to international standards to sustain a powerful transit system. The Lahore BRT is located in the provisional capital and their point induction is based on overcrowding and maintenance problems so they were able to win the score of 47. There were other issues related to poor infrastructure and lack of management skills that have triggered these problems. Another study was conducted in Tehran, Iran with the application of part standards 2013 for the evaluation of selected lines operating within 18 stations over a 14.4 km long route. They were able to win a score of 50 as their rank was quite closer to the bronze rank while the low scoring is due to the aspects of integration and weaknesses in infrastructure were recorded from 1000 boarded passengers [32].

CHAPTER 3: METHODOLOGY

Following is the flow chart explaining the methodology of study.

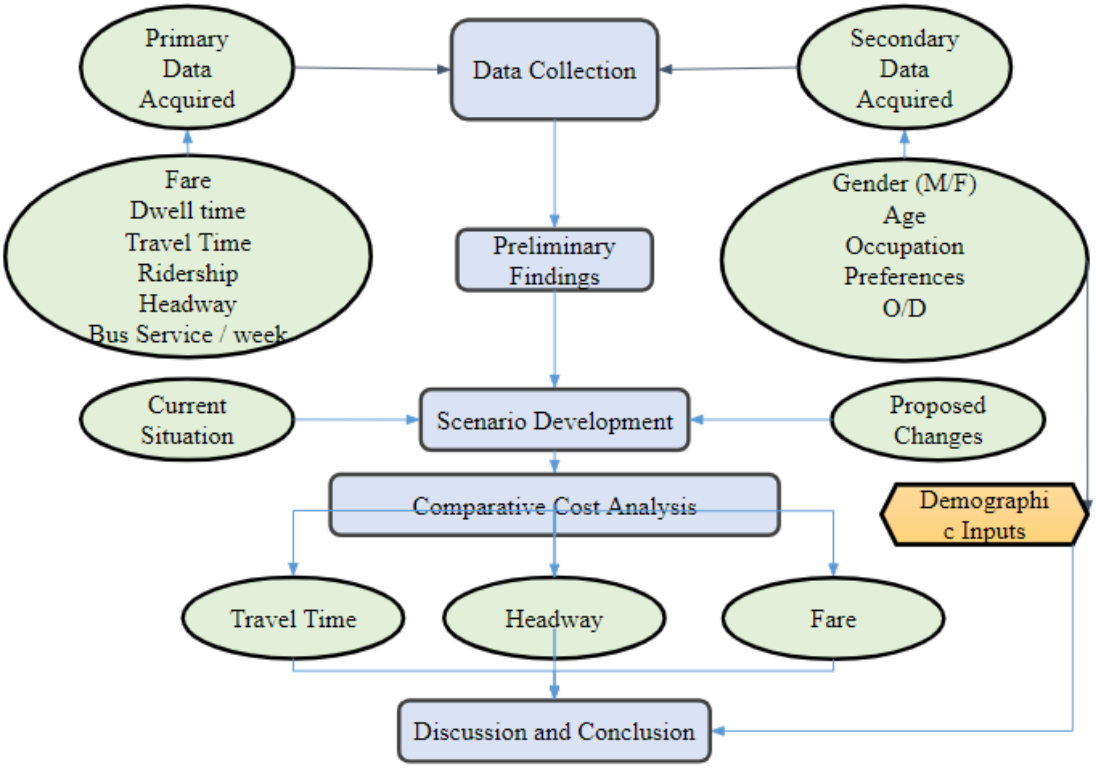

Figure 3-1: Methodology Framework

3.1 Data Collection / Current Situation

The dataset for this study is comprised of two parts. The Data collected through Punjab Mass Transit Authority and secondary information data is through questioner survey. The primary dataset consists of Fare, Dwell time, Travel time, Headway and Bus services in week. It was obtained through Punjab Mass transit authority. However, the information on gender, preferences, age, occupation are collected through survey. Origin/destination survey is used to analyse the productivity of each stop along the

route. The secondary dataset illustrates about the performance of Multan bus rapid transit.

3.2 Data Sorting

The data obtained from questionnare was expressed in spreadsheets for further analysis purpose. It was further scroutnized and to achive required sample size of 200 with error ratio of 10%. The sample size of the dataset is based on the following equation.

$$n = \frac{N}{1+Ne^2} \qquad \text{Eq. (4)}$$

where:

n = No. of samples

N = Total Demand

e = Error margin / margin of error

3.3 Scenario Development

3.3.1 Proposed Situation

The current BRT existing data including: features, demand, ridership, waiting time, number of stops, bus fare, etc. On the Basis of results the gaps has been found and figured out the gaps in the existing services and subsequently proposing intervention to address current challenges and evaluating on the basis of performance, generalized cost, and reduction in travel time and fare costs.

It has been analysed that the Time and Occupancy during the peak time are the major concern for public as competing modes provide less travel time by having limited stops during the trip. The Bus stops for Express are considered on the basis of onboarding and alighting data through origin destination survey. Origin Destination survey has been conducted on Origins to find the destination of passengers. The total Origins are divided to destination data to find the most preferred stops while greater than 6% alighting stops are considered for the Express bus service. Express bus service will reduce the travel time of BRT by 10 min from BZU to CKW terminal with the stop of Chungi no. 6, Chungi no. 9, Vehari chowk and Kumharan wala Chowk. These stops comprised of Commercial Areas.

Express Bus service will have less travel time as compared to present BRT service due to less number of stops. The BRT route start at Bahauddin Zakariya University in northern Multan as the major number of BRT Multan users are students and heads southward to Chungi number 6. Chungi No 6 is next to Khurshid Colony. It is the hub of educational institutes and hostels. Gardazy market is a well-known market in this area. This area is considered as a CBD for new development of Multan.

The route then pass by the eastern edge of Multan's to Vehari chowk which is the most highest ridership stop due to General bus stand. The route finally terminate at the Kumharan Wala chowk which is connected to densily populted area.

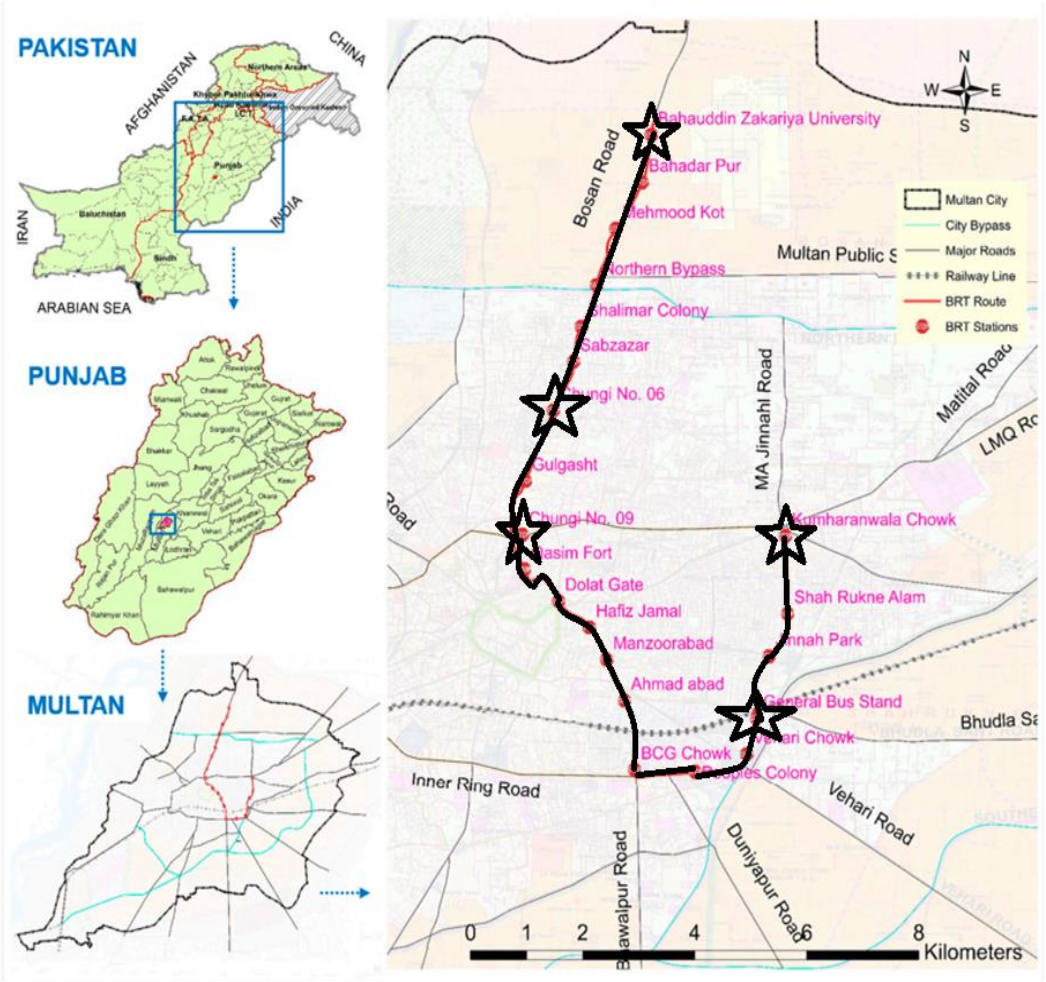

Figure 3-2: Proposed Route Express Bus Service

3.4 Analysis

Based upon the passenger satisfaction level which includes the performance indicators such as facilities for disabled personnel, location of BRT stations, the performance of escalators, fare collection process and points, platform boarding, time to the fare collection point, time from fare collection point to bus platform, informatory signs at the bus station, maintenance of buses and bus stations, bus speed, waiting time at the station, waiting time, operational hours and performance of BRT at peak hours

After completion of analyzing data, the major factors affecting the ridership and the utilization of BRT Multan. The data provided by PMA (main data source) helped a

lot in analyzing the ridership frequency. Furthermore, the data collected during the observation survey and questioner survey helped in evaluating the BRT affordability and effectiveness from user perception.

3.4.1 Passenger Waiting Time

The passenger waiting time is related with BRT service frequency i.e., for random passenger arrivals and headways <= 10 minutes (short headways), the average waiting time is half (1/2) of the headways while for headways >10 minutes (longer headways), Schedule of passengers are assumed (still the waiting time is a little longer). The waiting time is mathematically determined from the following Eq. (1).

$$WT = \begin{bmatrix} \frac{h}{2} & h \leq 10 \\ 10 - 5e^{\left\lceil 1 - \frac{h}{2} \right\rceil} & h > 10 \end{bmatrix} \qquad \text{Eq. (1)}$$

where:

WT = waiting time in minutes

h = the headway in minutes

This equation predicts that for headways greater than 10 minutes, the wait time increases directly as the headway increases but converges to a maximum waiting time of ten minutes as empirically validated by Lam and Morall (1982) [33]. While considering waiting time, the traveler may opt one out of the three alternatives, trip without transfer, trip with transfer and/or the low-cost alternative. If the traveler prefers the single seat ride, it is assumed that his waiting time increases as to avoid a seat transfer. Regardless of the transfer, the user can reduce waiting time by boarding the first arriving vehicle. The substitute that will be used in this proposed project is the assumption that transit user will opt the lowest generalized cost alternative [33].

3.4.2 Transfer Time Analysis

The time required on average to transfer between two lines with headways h1 and h2 would be estimated with the help of method developed by Vuchic (2005) in the form of equation below.

$$ET(TT) = min\left\{\frac{h1}{2}, \frac{h2}{2}\right\} \qquad \text{Eq. (2)}$$

where:

E(TT) = the average transfer time in minutes

h1 = the origin headway in minutes

h2 = the origin headway in minutes

The transfer time computation will be done along the feeder routes as no transfers are required for the trips along the main corridor route.

3.4.3 Generalized Cost Computation

Once the variation in each cost element (waiting time of passenger, in-vehicle time of passenger and transfer time), then the generalized cost between the origin and destination (O-D) can be easily determined with the help of mathematical equation given below.

$$\text{GCOD} = (\alpha 1 WT + \alpha 2 IVTT + \alpha 3 TT)\frac{VOT}{60} + fare \qquad \text{Eq. (3)}$$

where:

GCOD = the generalized cost from origin to destination

WT = the waiting time in minutes,

IVTT = the in-vehicle in minutes

TT = transfer time in minutes

VOT = value of time Rs/hr

Fare = transit fare in Rs

α1 = the relative weight of cost component i

In traveler perception, the passage of time is perceived differently for a different portion of the travel i.e., WT(waiting time), in-vehicle time and TT(transfer time). The values recommended by Kittelson et al. (2003), for the relative weights of the cost component will be used in this project. Due to the relative weights of the cost components are not known locally. The values of the cost components are presented in the Table 3-1 below.

Table 3-1: Cost Components

Sr. no.	**Cost Component**	**Value**
1	Wait Time (α_1)	2.1
2	In-vehicle Time (α_2)	1.0
3	Transfer Time (α_3)	2.5

Our prime concern is the reduction in generalized cost for transit users after the introduction of BRT Multan services. Calculating elasticity is the most effective and practical method for assessing how changes in the facility's pricing would affect demand (ratio of change in demand to change in price) of the demand with respect to price. In this study, the difference in generalised travel costs between specific origin

and destination pairs was calculated. This gives insight into the typical advantages of travelling along the corridor. The number of trips taken relative to their anticipated reduction in generalised cost is weighted in the final calculation of the wide decrease in generalised cost.

3.4.4 BRT Performance Evaluation

The BRT performance was evaluated with reference to the standards device by ITDP standards which provide a bench mark and a framework for infrastructure designers, policy makers and decision makers to implement the best BRT systems. Depending on the grading method, the BRT might be categorised as meeting gold, silver, or bronze standards. hence providing world-wide BRT routes of the highest standard. The assessment score consists of both the design score and the operation score. Interviews and surveys of PMA personnel were used to gather the information for the evaluation of BRT Multan.

The evaluation of the bus rapid transit system is based on the opinion of transit users. Thus, the information from survey, interviews and the data from transit bus authority was utilized. The primary constraints for system performance were obtained majorly from the observation at all the stations of the system and secondly from the data provided by the transit authority. Using the available data and simple mathematic equations, different elements representing the system performance were calculated.

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Passenger's Statistics and Characteristic

The sample distribution data analysis results showed a proportion of males and females of 60% and 40% respectively. The data based on the questionnare survey from 200 users are computed in Table 4-1 below.

Table 4-1: Statistics based on Questionnaire Survey

S/No.	Characteristics	Proportion
1	Gender	Male [60%], Female [40%]
2	Qualification	Prim [10%], high [28%], Graduate [30%], post-grad [8%]
3	Age	<18 [22%], 18-30 [55%], 30-45 [17%]
4	Profession	Students [55%], Employees [25%], labor [10%],
5	Access to BRT	Bus [30%], Rickshaw [25%], Motorcycle [25%], Car [15%]
6	Weakly Frequency using BRT	First-time [7%], Once a week [3%], 2-3 days [42%], 4-7[50%]
7	Origin of travel	Home [70%], work [11%], Education [15%], shop [4%]
8	Destination of Travel	Education [55%], Work [30%], home [13%], shop [2%]
9	Payment/fare	BRT Card [55%], Cash [45%]
10	BRT Preference Reasons	Comfort [55%], Time [22%], Money [28%]

4.2 Ridership Statistics

The data provided by the Punjab Mass Transit Authroity (PMA) is summarized in the Table 4-2 below.

Table 4-2: Service Details of BRT Multan

S/No.	Description	Details
1	Number of Stops	21 stops
2	Average of Ridership	28820
3	System Service Hrs	16 hours daily
4	Time of Service	6 AM to 10 PM
5	Peak Hours	7 AM to 10 AM and 4 PM to 8 PM
6	Frequency of Buses in Peak hrs	21 buses per hour
7	Frequency of Buses in Off Peak hrs	21 – 18 buses per hour
8	Headways Peak Hrs.	7 Min
9	Headways Off Peak Hrs.	5 Min
10	maximum travel time	1hr 21 sec
11	minimum travel time	45 min
12	Number of Trips in a week	389 Trips on Monday 361/day Tuesday to Saturday 348 Sunday
13	Dwell Time	30 sec
14	Commercial Speed	26 km/hr
15	Maximum Speed	45 km/hr
16	Occupancy	1.026
17	Fare	20 rupee

18	Distance travel each day	17246 km
19	Line capacity	3525 person/hour/direction

Currently other modes of transportation are the major concern in the ridership of BRT Multan. According to the survey it has been calculted that 3000 rikshaws are moving on the route of BRT Multan while local Hi-Ace route are the main source of competition with less travel time.

The range of average daily ridership for each month lies from 25000 to just above 33000 with the maximum observed value of 33,300 for the month of October 2021. Therefore, the annual average daily ridership is equal to almost 28,820 travellers every day.

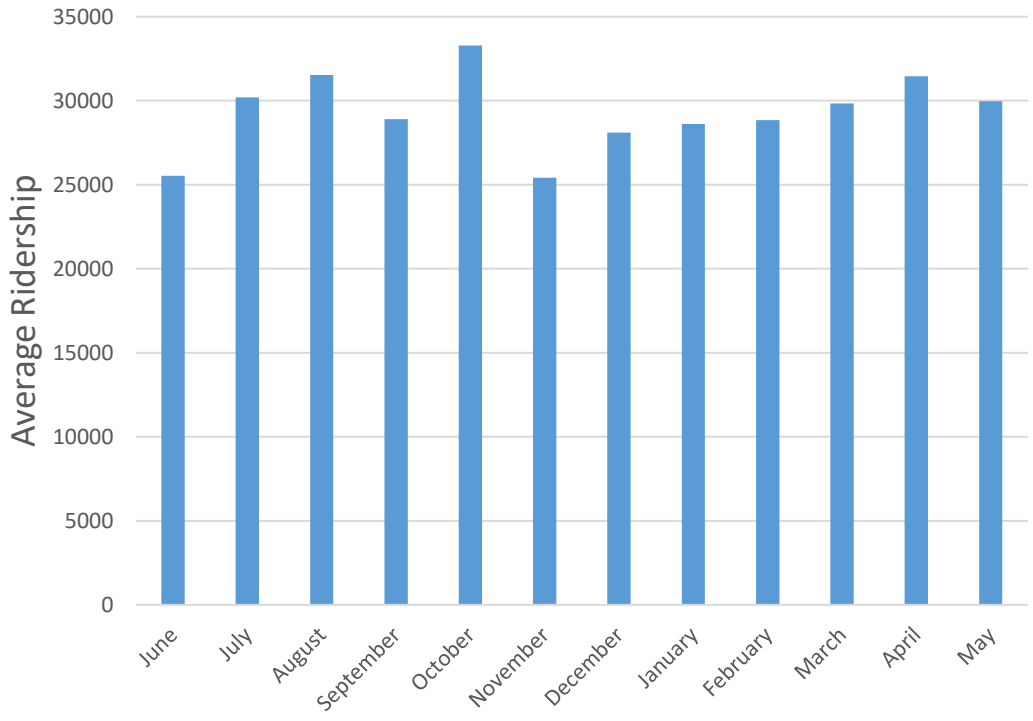

Figure 4-1: Distribution of Average Daily Ridership on Monthly Basis for the Year of 2021

The weekly ridership for the month of April 2021 was also plotted as can be seen in the fig 4-7 below. As the main origin of the BRT transit user was home and the most frequent destination was educational institutes, therefore the month of April-2021 was selected to have a better understanding of the BRT ridership. In week-3(3rd week of the month) of the observation period, Tuesday has a relatively low ridership due to off-day of the schools. The average ridership is around 30,000 approximately.

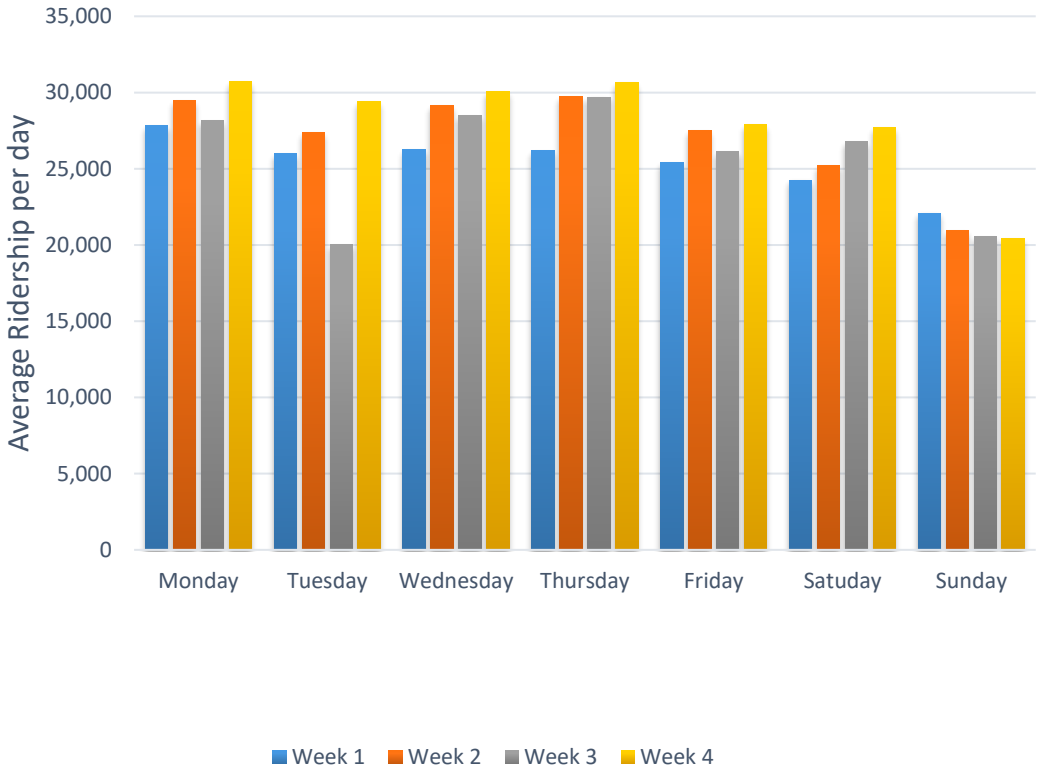

Figure 4-2: Distribution of Weekly Ridership Trend For the Month of April

The design, durability and maintenance of a given system can be determined by quantifying the number of faults or failures in a specified duration of time. The data provided by MPA (as plotted below) describes the failures the buses experiences during the articulated time (from June 2020 to May 2021). A total of 7 mechanical failures

were recorded in the spatulated time. Thus, the smaller number of mechanical failures shows the better performance of BRT Multan.

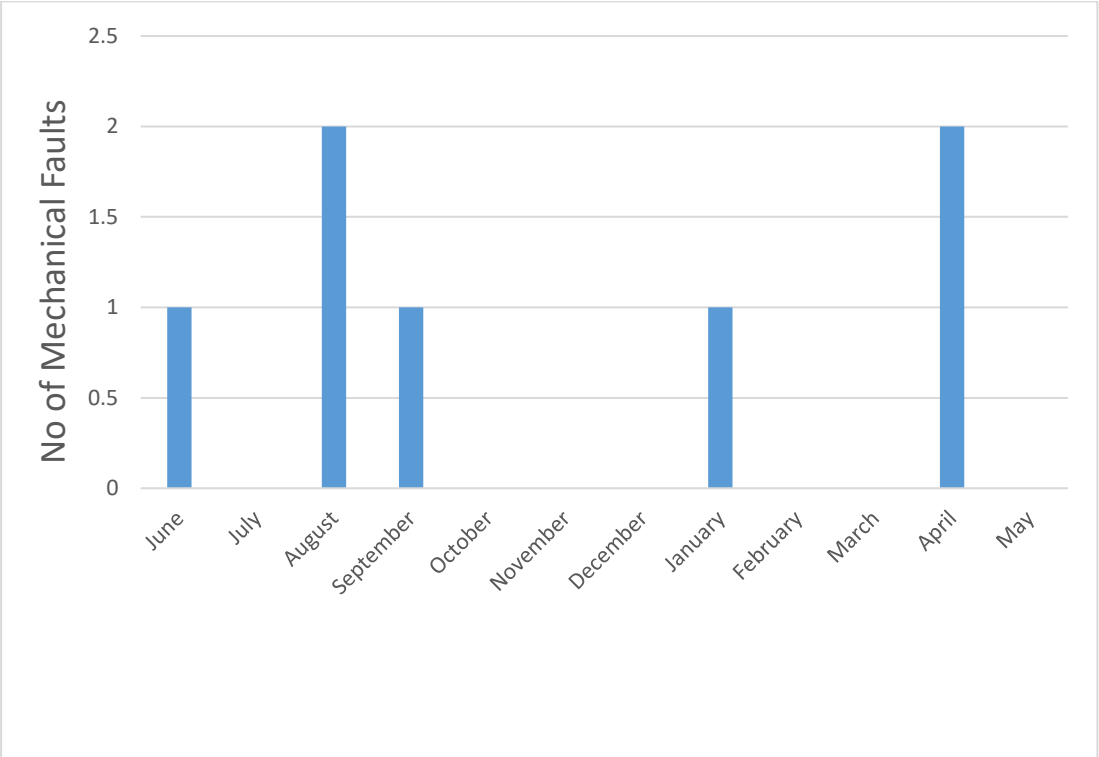

Figure 4-3: Periodic Mechanical Maintenances of Buses

4.3 BRT Multan as per ITDP standard

The BRT system was evaluated on the BRT Standard Scorecard 2016 as standard of ITDP. The score of BRTS Multan against various aspects were found to be satisfactory. On a scale of 0-100 the BRT Multan earned a value of 82 points (Range 70-84) which is specified as silver category according to BRT standards.

Table 4-3: Score of BRT Multan as per ITDP

S/No.	CATEGORY	Maximum Score	Multan BRT Score
	BRT BASICS		
1	Dedicated Right-of-Way	8	8
2	Busway Alignment	8	8
3	Off- Board Fare Collection	8	8
4	Intersection Treatments	7	7
5	Platform- Level Boarding	7	7
	Total	38	38
	SERVICE PLANNING		
1	Multiple Routes	4	0
2	Express, Limited-Stop, and Local Service	3	0
3	Control Center	3	3
4	Located in Top Ten Corridors	2	2
5	Demand Profile	3	3
6	Hours of Operations	2	2
7	Multi-Corridor Network	2	2
	Total	19	12
	INFRASTRUCTURE		
1	Passing Lanes at Stations	3	3
2	Minimizing Bus Emissions	3	0
3	Stations Set Back from Intersections	3	3
4	Center Stations	2	2
5	Pavement Quality	2	1
	Total	13	9
	Station		
1	Distances Between Stations	2	2
2	Safe and Comfortable Stations	3	3
3	Number of Doors on Bus	3	3
4	Docking Bays and Sub-Stops	1	1
5	Sliding Doors in BRT Stations	1	1
	Total	10	10
	COMMUNICATIONS		
1	Branding	3	3

2	Passenger Information	2	2
	Total	5	5
	ACCESS AND INTEGRATION		
1	Universal Access	3	2
2	Integration with other Public Transport	3	2
3	Pedestrian access and Safety	4	4
4	Secure Bicycle Parking	2	0
5	Bicycles Lanes	2	0
6	Bicycle-Sharing Integration	1	0
	Total	15	8
	TOTAL SCORE	100	82

Table 4-4: Category of BRT Multan as per ITDP standard

S/No.	**ITDP BRT Standard**	**MAXIMUM SCORE**	**MULTAN BRT SCORE**
1	BRT GOLD	85–100	
2	BRT SILVER	70–84.9	X
3	BRT BRONZE	55–69.9	
4	NOT BRT	BELOW 54.9	

As BRT Multan is performing very well, therefore there was 0 deduction score awarded. The systems transport more than 1000 passengers per hour per direction during peak rush hours while maintaining acceptable commercial speed and having negligible probability of encroachment due to fencing all along the corridor. Also, the BRT service experiences no overcrowding.

Table 4-5: Points deduction of BRT Multan

S/No.	POINTS DEDUCTIONS	MAXIMUM SCORE	MULTAN BRT SCORE
1	Commercial Speeds	-10	0
2	Lack of Enforcement of Right-of-Way	-5	0
3	Overcrowding	-5	0
4	Permitting Unsafe Bicycle Use	-2	0
5	Lack of Traffic Safety Data	-2	0
6	Buses Running Parallel to Brt Corridor	-6	0
7	Bus Bunching	-4	0
8	Low off-Peak Frequency	-2	0
9	Low Peak Frequency	-3	0
10	Poorly Maintained Infrastructure	-14	0
11	Peak Passenger per hr per direction	-5	0

(Source:ITDP.org)

a. Transit User Response

The outcome of the survery conducted from the user on various station, the results revealed that almost 93% respondents strongly agree that their bus is on time and a much less 7% of the passengers strongly disagreed with the fact that theirs bus always late. The main reason of transit user disagreement was concluded from the further analysis of data. Thus, the BRT Multan is reliable public transport facility for the city residents. The analyzed survey data is graphically presented in the Bar-chart in Figure 4-4 below,

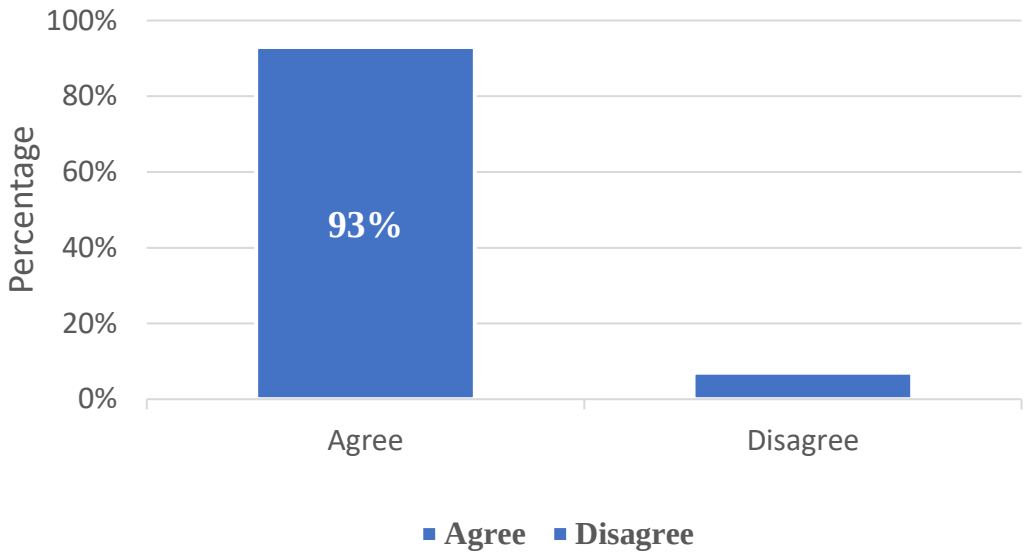

Figure 4-4: Transit User Response

4.4 Quality of BRT Multan:

According to the transit users seat availability is very important and about 45% of the respondents strongly disagreed to the statement that they found seat to sit in the bus. The assessment of the passenger amenities at the station concluded that as many as 96% of the responded agreed that the shelter provided at the station protect them from sun and rain. About 97.3% of the passenger agreed that the buses are clean and that the stations are well lighted at the night time. Water Cooler are available at all the stations and public washrooms are also provided for transit users.

The adherence to time schedule, high frequency of the transit system and information's delivery at the station is among the most reliable aspects of the BRT Multan according to passenger response. The respondents were quite happy with the security of the station, about 78.8% of the respondents feel safe at the day time while 65.38% strongly agreed that the transit stations are safe at night and that they feel even

safer in the presence of a security guard. The qualitative aspects of the transit facility can be summarized in the form of graph as shown in Figure 4-5 below.

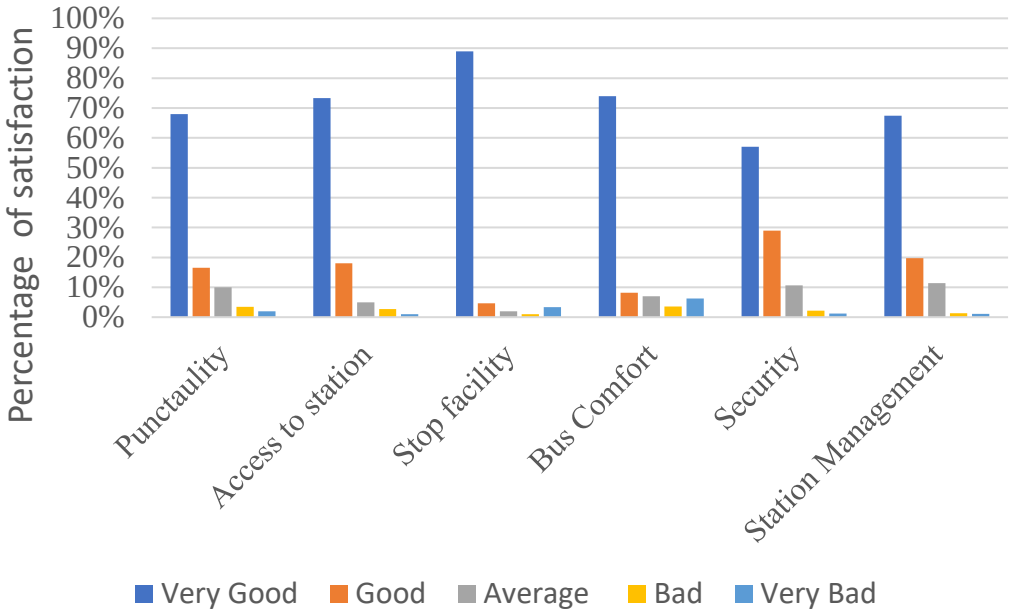

Figure 4-5: Quality of BRT Multan

4.5 Travel Time of BRT Multan

Total of 45:27 min has been consumed to cover the distance between Bahauadin Zakariya University terminal to Kumaharan wala.The difference of 10sec has been observed in opposite direction due to the geometric design of Multan Metro Bus service with a value of 45:37 min.

No route need a transfer. In Annex A, the procedures for calculating the change in generalised cost are outlined. Express introduction lowers generalized costs between these origin-destination pairings by 0 to 17.9 percent because to the decreased in-vehicle and waiting periods.

Table 4-6: Travel time comparison

S/No.	STATION NAME	Planned Time (in Minutes)	Express Bus Planned Time (in Minutes)
1	Bahauddin Zakarya University	00:00	00:00
2	Bahadarpur	01:45	-
3	Mehmood Kot	03:30	-
4	Nothern Bypass	05:51	-
5	Shalimar Colony	07:20	-
6	Sabzazar	08:45	-
7	Chungi No. 6	10:30	07:30
8	Gulgasht	13:14	-
9	Chungi No. 9	17:42	13:42
10	Qasim Fort	21:00	-
11	Dolat Gate	23:42	-
12	Hafiz Jamal	25:45	-
13	Manzoorabad	27:03	-
14	Ahmedabad	28:39	-
15	BCG Chowk	31:20	-
16	Peoples Colony	34:25	-
17	Vehari Chowk	37:12	29:12
18	General Bus Statnd	38:36	-
19	Jinnah Park	40:56	-
20	Shah Rukn-e-Alam	42:40	-
21	Kumharan wala Chowk	45:27	35:30

4.6 Proposed Mitigation Measure

Express will link origins and destinations that were formerly covered by Metro Bus service. Because 78 percent of respondents to the current poll said they favoured the BRT for its comfort and affordability, consumers will prefer it for trip time. This will help in increasing the ridership as users will prefer the service with generalized

Cost Travel time will be reduced by 9 min 57 sec with the express bus service which will reduce about the generalized cost from 0 to 17.9 percent. 5 min has been considered as a headway for Express bus service for the peak hrs due to high occupancy. 25 rupee fare has been considered for the fare for the Express bus service.

CHAPTER 5: CONCLUSION

Our study results has indicated an increase that commuter has more inclined towards less travel time among all other factors. Additionally, an introdution of feeder route would serve as fruitful in enhacing demand. Therefore, they have forced to choose other modes (e.g. taxi, and paratransit – chinchi etc.) for their trip purposes. However, our study has figured that the congested road network at peak and off-peak times is the primarly attrection in choosing BRT line as it enhances their comfort level. Additional factors that govern commuters choice was found as bus fare. The service offering a quality of service in a subsidies fare value, independent of being linked with an inflation, was not expected and experienced with private transporters. This inidcates that the public office, in future, should consider quality and trip fare/price value as non-compromisable, if they want to go for pravitization in future. Moreover, performance evaluation has revealed that the upgradation of services in the BRT would be fruitful in user's prefernce inclined towards BRT. Such soft measures will able to achieve ridership demand of the BRT as proposed in feasilbity study. Last but not the least, it is a time of need to have an integrated sustainable transport policy, and for that it needs an input from professionals and researchers from industry and academia jointly involve in doing brain stroming excercises leasding towards sustainable objectives.

RECOMMENDATIONS

This research recommends the following key policy implications for future BRT system in Pakistan.

- Improvements in several sectors of the available BRT Multan should be made under the ITDP Rating standard, so that the BRT score get improved.
- Park and ride option should be introduced to increase the ridership of the usage of Bicycle users.
- Policies should be made to ensure that the commuters maximize the usage of public transport as their daily mode of travel due to increasing fuel prices.
- Express service should be introduced to decrease the travel time so that users get attracted to given service.

REFERENCES

1. Bamwesigye, D. and P. Hlavackova, *Analysis of sustainable transport for smart cities.* Sustainability, 2019. **11**(7): p. 2140.

2. Handy, S., *Planning for accessibility: In theory and in practice*, in *Access to destinations*. 2005, Emerald Group Publishing Limited.

3. Sampaio, B.R., O.L. Neto, and Y. Sampaio, *Efficiency analysis of public transport systems: Lessons for institutional planning.* Transportation research part A: policy and practice, 2008. **42**(3): p. 445-454.

4. Khan, F., et al., *An Evaluation of Cost Optimization Strategies for BRT Projects in Pakistan.* Engineering, Technology & Applied Science Research, 2022. **12**(4): p. 8825-8830.

5. Joewono, T.B. and H. Kubota, *Safety and security improvement in public transportation based on public perception in developing countries.* IATSS research, 2006. **30**(1): p. 86-100.

6. Shah, S.A.R., et al., *Performance evaluation of bus rapid transit system: A comparative analysis of alternative approaches for energy efficient eco-friendly public transport system.* Energies, 2020. **13**(6): p. 1377.

7. Kepaptsoglou, K., et al., *Comparing traveler preferences for BRT and LRT systems in developing countries: Evidence from Multan, Pakistan.* Journal of Traffic and Transportation Engineering (English Edition), 2020. **7**(3): p. 384-393.

8. Imran, M., *Public transport in Pakistan: a critical overview.* Journal of Public Transportation, 2009. **12**(2): p. 4.

9. Nadeem, M., et al., *Does Bus Rapid Transit System (BRTS) meet the citizens' mobility needs? Evaluating performance for the case of Multan, Pakistan.* Sustainability, 2021. **13**(13): p. 7314.

10. Kepaptsoglou, K., et al., *Modeling LRT versus BRT preferences in developing countries: The case of Multan, Pakistan*. 2016.

11. Batool, I., M. Irshad, and M. Abid, *A Policy Move towards Sustainable Urban Transport in Pakistan: Measuring the Social, Environmental and Economic Impacts of Lahore BRT System.* Lahore Journal of Economics, 2020. **25**(1): p. 27-57.

12. Motta, R.A., P.C.M. Da Silva, and M.P.D.S. SANTOS, *Crisis of public transport by bus in developing countries: a case study from Brazil.* International journal of sustainable development and planning, 2013. **8**(3): p. 348-361.

13. Allen, J. and S. Farber, *Planning transport for social inclusion: An accessibility-activity participation approach.* Transportation Research Part D: Transport and Environment, 2020. **78**: p. 102212.

14. Racehorse, V.J., et al., *Bus rapid transit system deployment for high quality and cost-effective transit service: a comprehensive review and comparative analysis.* IET Intelligent Transport Systems, 2015. **9**(2): p. 175-183.

15. Berdiyorov, T. *Metrobus in separated corridors as an optimal public transport system*. in *IOP Conference Series: Earth and Environmental Science*. 2020. IOP Publishing.

16. Satiennam, T., A. Fukuda, and R. Oshima, *A study on the introduction of bus rapid transit system in Asian developing cities: A case study on Bangkok Metropolitan Administration Project.* IATSS research, 2006. **30**(2): p. 59-69.

17. Haider, F., et al., *Performance evaluation of BRT standard in decision support system for integrated transportation policy.* Sustainability, 2021. **13**(4): p. 1957.

18. Rathore, K. and K. Ali, *Evaluation of Lahore Bus Rapid Transit System.* International Journal of Management Sciences and Business Research, 2015. **4**(10).

19. Ahmed, H.U. and A. Azeem, *Evaluation of System Performance of Metro Bus Lahore*. 2015.

20. Panchore, V. and N. Khushwaha, *Performance evaluation of brts.* IJSTE-International Journal of Science Technology & Engineering, 2016. **2**(11): p. 509-512.

21. Seraj, M., et al., *Traveler preference analysis for the proposed bus Rapid Transit (BRT) service in Dhaka.* Journal of Civil Engineering (IEB), 2015. **43**(2): p. 133-144.

22. Fatima, E. and R. Kumar, *Introduction of public bus transit in Indian cities.* International Journal of Sustainable Built Environment, 2014. **3**(1): p. 27-34.

23. Deng, T. and J.D. Nelson, *Recent developments in bus rapid transit: a review of the literature.* Transport Reviews, 2011. **31**(1): p. 69-96.

24. Tskeris, T. and C. Tsekeris, *Demand forecasting in transport: Overview and modeling advances.* Economic research-Ekonomska istraživanja, 2011. **24**(1): p. 82-94.

25. Litman, T., *Transit price elasticities and cross-elasticities.* Journal of Public Transportation, 2004. **7**(2): p. 3.

26. Holmgren, J., *Meta-analysis of public transport demand.* Transportation Research Part A: Policy and Practice, 2007. **41**(10): p. 1021-1035.

27. Hensher, D.A. and T.F. Golob, *Bus rapid transit systems: a comparative assessment.* Transportation, 2008. **35**(4): p. 501-518.

28. Dell'Olio, L., A. Ibeas, and P. Cecin, *The quality of service desired by public transport users.* Transport Policy, 2011. **18**(1): p. 217-227.

29. Alçura, G.A., et al., *Impact score technique for analyzing the service quality of a high-speed rail system.* Transportation Research Record, 2016. **2541**(1): p. 64-72.

30. Barabino, B., E. Deiana, and P. Tilocca, *Urban transport management and customer perceived quality: a case study in the metropolitan area of Cagliari, Italy.* Theoretical and Empirical Researches in Urban Management, 2011. **6**(1): p. 19-32.

31. Khalid, U.A., et al., *User perceptions of rail public transport services in Kuala Lumpur, Malaysia: KTM Komuter.* Procedia-social and behavioral sciences, 2014. **153**: p. 566-573.

32. Allen, H., *An integrated approach to public transport, Tehran, Islamic Republic of Iran.* Global Report on Human Settlements, 2013.

33. Casello, J.M. and B. Hellinga, *Impacts of express bus service on passenger demand.* Journal of Public Transportation, 2008. **11**(4): p. 1.

ANNEXTURES

Table A- 1: Percentage of Alighting on Different Stops of BRT

	1600-BZU	1601-BAHADAR PUR	1602-MEHMOODKOT	1603-NORTHERN BYPASS	1604-SHALIMAR COLONY	1605-SABZAZAR	1606-CHUNGI NO. 06	1607-GULGASHT	1608-CHUNGI NO. 09	1609-QASIM FORT	1610-DOLATGATE	1611-HAFIZJAMAL	1612-MANZOORABAD	1613-AHMADABAD	1614-BCG CHOWK	1615-PEOPLES COLONY	1616-VEHARI CHOWK	1617-GENERAL BUS STAND	1618-JINNAH PARK	1619-SHAHRUKNE ALAM	1620-KUMHARANWALA CHOWK
1600-BZU	-	0.163%	0.327%	0.472%	0.599%	0.327%	0.744%	0.399%	0.943%	0.707%	0.236%	0.381%	0.254%	0.218%	0.635%	0.236%	1.687%	0.744%	0.435%	0.399%	0.580%
1601-BAHADAR PUR	0.145%	-	0.054%	0.218%	0.073%	0.127%	0.345%	0.200%	0.562%	0.073%	0.200%	0.073%	0.109%	0.127%	0.127%	0.109%	0.508%	0.145%	0.127%	0.145%	0.236%

1602-MEHMOOD KOT	0.290%	0.073%	-	0.218%	0.109%	0.073%	0.617%	0.145%	0.580%	0.054%	0.073%	0.036%	0.073%	0.091%	0.163%	0.073%	0.200%	0.163%	0.109%	0.127%	0.218%
1603-NORTHERN BYPASS	0.526%	0.308%	0.290%	-	0.145%	0.091%	0.562%	0.308%	0.617%	0.272%	0.254%	0.073%	0.327%	0.200%	0.200%	0.127%	0.472%	0.145%	0.163%	0.127%	0.345%
1604-SHALIMAR COLONY	0.562%	0.073%	0.145%	0.127%	-	0.200%	0.327%	0.254%	0.381%	0.054%	0.054%	0.073%	0.127%	0.127%	0.181%	0.054%	0.453%	0.181%	0.091%	0.109%	0.254%
1605-SABZAZAR	0.308%	0.127%	0.091%	0.109%	0.236%	-	0.290%	0.073%	0.417%	0.091%	0.181%	0.163%	0.109%	0.073%	0.145%	0.036%	0.381%	0.145%	0.091%	0.036%	0.327%
1606-CHUNGINO.06	0.707%	0.345%	0.381%	0.345%	0.308%	0.290%	-	0.236%	0.562%	0.327%	0.200%	0.308%	0.236%	0.163%	0.236%	0.163%	0.925%	0.163%	0.254%	0.200%	0.381%

1607-GULGASHT	0.453%	0.200%	0.163%	0.327%	0.236%	0.091%	0.218%	-	0.218%	0.2054%	0.0073%	0.0091%	0.163%	0.054%	0.2018%	0.1027%	0.3063%	0.2000%	0.1027%	0.181%	0.308%
1608-CHUNGINO.09	0.961%	0.327%	0.508%	0.254%	0.345%	0.381%	0.490%	0.200%	-	0.2000%	0.2090%	0.1063%	0.054%	0.236%	0.2072%	0.2000%	1.2033%	0.1027%	0.2054%	0.127%	0.526%
1609-QASIMFORT	0.744%	0.127%	0.127%	0.308%	0.054%	0.127%	0.200%	0.290%	0.200%	-	0.109%	0.1063%	0.127%	0.054%	0.109%	0.0054%	0.4090%	0.1081%	0.1027%	0.109%	0.254%
1610-DOLATGATE	0.218%	0.145%	0.091%	0.218%	0.036%	0.200%	0.163%	0.091%	0.163%	0.0054%	-	0.0036%	0.109%	0.127%	0.2018%	0.0091%	0.2054%	0.3027%	0.1063%	0.127%	0.200%
1611-HAFIZJAMAL	0.327%	0.054%	0.036%	0.327%	0.109%	0.127%	0.236%	0.073%	0.127%	0.1027%	0.0091%	-	0.109%	0.163%	0.2018%	0.1027%	0.2018%	0.1027%	0.0073%	0.163%	0.308%
1612-MANZOORABAD	0.236%	0.091%	0.073%	0.272%	0.145%	0.091%	0.218%	0.145%	0.073%	0.0073%	0.1027%	0.1091%	-	0.163%	0.1027%	0.0091%	0.1027%	0.1091%	0.1045%	0.054%	0.272%

1613-AHMADABAD	0.200%	0.073%	0.073%	0.290%	0.127%	0.054%	0.236%	0.073%	0.036%	0.109%	0.163%	0.127%	0.127%	-	0.073%	0.163%	0.327%	0.236%	0.091%	0.163%	0.490%
1614-BCG CHOWK	0.671%	0.109%	0.200%	0.218%	0.200%	0.127%	0.218%	0.272%	0.308%	0.091%	0.200%	0.200%	0.109%	0.091%	-	0.254%	0.417%	0.236%	0.200%	0.218%	0.417%
1615-PEOPLES COLONY	0.254%	0.091%	0.054%	0.127%	0.036%	0.054%	0.145%	0.109%	0.127%	0.109%	0.036%	0.127%	0.091%	0.036%	0.290%	-	0.218%	0.236%	0.127%	0.145%	0.290%
1616-VEHARI CHOWK	1.705%	0.580%	0.218%	0.435%	0.435%	0.399%	0.871%	0.345%	1.179%	0.399%	0.290%	0.200%	0.145%	0.345%	0.381%	0.308%	-	0.635%	0.200%	0.417%	0.816%
1617-GENERAL BUS STAND	0.762%	0.145%	0.345%	0.327%	0.200%	0.200%	0.218%	0.254%	0.127%	0.200%	0.163%	0.218%	0.109%	0.163%	0.236%	0.109%	0.599%	-	0.054%	0.181%	0.218%

1618-JINNAH PARK	0.472%	0.036%	0.109%	0.200%	0.109%	0.073%	0.054%	0.073%	0.127%	0.073%	0.109%	0.054%	0.163%	0.127%	0.200%	0.109%	0.181%	0.109%	-	0.200%	0.236%
1619-SHAH RUKNE ALAM	0.381%	0.054%	0.091%	0.290%	0.073%	0.018%	0.200%	0.145%	0.091%	0.127%	0.054%	0.163%	0.073	0.163%	0.272%	0.054%	0.381%	0.218%	0.127%	-	0.381%
1620-KUMHA RANWA LA CHOWK	0.635%	0.381%	0.381%	0.308%	0.381%	0.308%	0.490%	0.290%	0.508%	0.381%	0.272%	0.327%	0.236	0.308%	0.399%	0.036%	0.834%	0.200%	0.109%	0.109%	-

Table A- 2: Generalized Cost Comparison

Metro Bus Multan Existing						**Metro Express Route Proposed**					
In Vehicle travel Time (min)											
	BZU	Chungi no. 6	Chungi no. 9	Vehari Chowk	CKW		BZU	Chungi no. 6	Chungi no. 9	Vehari Chowk	CKW
BZU	-	0:10:30	0:17:42	0:37:12	0:45:30	BZU	-	0:07:30	0:13:42	0:29:12	0:35:30
Chungi no. 6	0:10:30	-	0:07:49	0:25:33	0:35:07	Chungi no. 6	0:07:30	-	0:06:12	0:21:42	0:28:00
Chungi no. 9	0:17:42	0:07:49	-	0:19:30	0:27:48	Chungi no. 9	0:13:42	0:06:12	-	0:15:30	0:21:48
Vehari Chowk	0:37:12	0:25:33	0:19:30	-	0:08:15	Vehari Chowk	0:29:12	0:21:42	0:15:30	-	0:06:18
CKW	0:45:37	0:35:07	0:27:51	0:08:15	-	CKW	0:35:30	0:28:00	0:21:48	0:06:18	-
TU headway (min/veh)											
	BZU	Chungi no. 6	Chungi no. 9	Vehari Chowk	CKW		BZU	Chungi no. 6	Chungi no. 9	Vehari Chowk	CKW
BZU		7	7	7	7	BZU		5	5	5	5
Chungi no. 6	7		7	7	7	Chungi no. 6	5		5	5	5
Chungi no. 9	7	7		7	7	Chungi no. 9	5	5		5	5

Vehari Chowk	7	7	7		7	Vehari Chowk	5	5	5		5
CKW	7	7	7	7		CKW	5	5	5	5	
Expected wait time (min)											
	BZU	Chungi no. 6	Chungi no. 9	Vehari Chowk	CKW		BZU	Chungi no. 6	Chungi no. 9	Vehari Chowk	CKW
BZU		3.5	3.5	3.5	3.5	BZU		2.5	2.5	2.5	2.5
Chungi no. 6	3.5		3.5	3.5	3.5	Chungi no. 6	2.5		2.5	2.5	2.5
Chungi no. 9	3.5	3.5		3.5	3.5	Chungi no. 9	2.5	2.5		2.5	2.5
Vehari Chowk	3.5	3.5	3.5		3.5	Vehari Chowk	2.5	2.5	2.5		2.5
CKW	3.5	3.5	3.5	3.5		CKW	2.5	2.5	2.5	2.5	
Total generalized cost. PKR											
	BZU	Chungi no. 6	Chungi no. 9	Vehari Chowk	CKW		BZU	Chungi no. 6	Chungi no. 9	Vehari Chowk	CKW
BZU	-	110.321	146.753	245.423	287.421	BZU	-	89.515	120.887	199.317	231.195
Chungi no. 6	110.321	-	96.7096	186.474	235.1512	Chungi no. 6	89.515	-	82.937	161.367	193.245
Chungi no. 9	146.753	96.7096	-	155.861	197.859	Chungi no. 9	120.887	82.937	-	129.995	161.367
Vehari Chowk	245.423	185.3608	155.861	-	98.936	Vehari Chowk	199.317	161.367	129.995	-	83.443

CKW	287.9776	235.1512	198.112	98.936	-	CKW	231.195	193.245	161.367	83.443	-

Reduction in generalized cost. (PKR)

	BZU	Chungi no. 6	Chungi no. 9	Vehari Chowk	CKW
BZU	-	20.806	25.866	46.106	56.226
Chungi no. 6	20.806	-	13.7726	25.107	41.9062
Chungi no. 9	25.866	13.7726	-	25.866	36.492
Vehari Chowk	46.106	23.9938	25.866	-	15.493
CKW	56.7826	41.9062	36.745	15.493	-

Reduction in generalized cost. (%)

	BZU	Chungi no. 6	Chungi no. 9	Vehari Chowk	CKW
BZU		18.86%	17.63%	18.79%	19.56%
Chungi no. 6	18.86%		14.24%	13.46%	17.82%
Chungi no. 9	17.63%	14.24%		16.60%	18.44%
Vehari Chowk	18.79%	12.94%	16.60%		15.66%
CKW	19.72%	17.82%	18.55%	15.66%	

Table A- 3: Generalized Cost Comparison

Sr.No.	**Route**	**Issuing Agency**	Operating agency	**Number of**	**Overlap**
1	GBS to Railway Station via Kumharan Wala Chowk, Masoom Shah Road, Daulat Gate, Hussain Agahi, Ghanta ghar, Katchehry Chowk, Kalma Chowk, Nawa Shehar, Derra Adda (Pics Attached at Annex-2)	(As said by Sec. DRTA Office)	Local Hi-ace	17	From Vehari Chowk to Kumharan Wala Chowk (4.2KM)
2	GBS to Head Sikandari Nala via Chungi No. 14, Hafiz Jamal Road, Daulat Gate, Hussain Agahi, Katchehry Chowk, MDA Chowk, Suraj Miani. (Pics Attached at Annex-4)	(As said by Sec. DRTA Office)	Local Hi-ace	10	From Chungi No. 14 to Daulat Gate (2KM)
3	General Bus Stand to Jhoke Wains via Kumharan Wala Chowk, Northern	(As said by Sec. DRTA Office)	Local Hi-ace	17	i.From Vehari Chowk to Kumharan Wala Chowk (4.2KM)ii.From Northern Bypass to BZU (3.2KM)

All Check-in / Chek-out cases as per fare integration structure.

		Start Journey		Transfer 1		Trnasfer 2		
		Trip 1		Trip 2		Trip 3		Total Fare
		Checkin	Checkout	Checkin	Checkout	Checkin	Checkout	
NO TRANSFER		Feeder						
	CASE 1	20	-5					15
		20	no Check out					
		MBS						
	CASE 2	20	0					20
		20	no Check out					20
		no Check in	20					20
1 TRANSFER		Feeder		MBS				
	CASE 3	20	-5	5	0			20
		20	no Check out	20	0			40
		20	no Check out	no Check in	20			40
		20	-5	5	no Check out			20
		20	-5	no Check in	20			35
		MBS		Feeder				
	CASE 4	20	0	5	-5			20
		20	no Check out	20	-5			35
		20	no Check out	no Check in	20			40
		20	0	5	no Check out			25
		20	0	no Check in	5			25
		Feeder 1		Feeder 2				
	CASE 6	20	-5	10	-5			20
		20	-5	no Check in	10			25
		20	-5	10	no Check out			25
2 TRANSFER		MBS		MBS				
	EX1	20	0	5	-5			N/A
		Feeder		MBS (T1+F60		Feeder (T2)		
	CASE 5	20	-5	5	0	10	-5	25
		20	-5	5	0	no Check in	10	30
		20	-5	5	0	10	no Check out	30
		Feeder		Feeder		Feeder		
	CASE 7	20	-5	10	-5	10	-5	25
		20	-5	10	-5	10	no Check out	30
		20	-5	10	-5	no Check in	10	30
		Feeder		Feeder		MBS		
	CASE 8	20	-5	10	-5	5	0	25
		20	-5	10	-5	5	no Check out	25
		20	-5	10	-5	no Check in	20	40
		MBS		Feeder		MBS		
	EX5	20	0	5	-5	5	0	25
		MBS		Feeder		Feeder		
	EX6	20	0	5	-5	10	-5	25