POST IMPLEMENTATION EVALUATION OF BUS RAPID TRANSIT SYSTEM (BRTS) RAWALPINDI-ISLAMABAD

By

Muhammad Sabir

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Certified that the contents and form of thesis entitled **“Post Implementation Evaluation of Bus Rapid System (BRTS) Rawalpindi - Islamabad”** submitted by Muhammad Sabir have been found satisfactory for the requirement of the degree of Masters of Science in Transportation Engineering.

Supervisor: ________________________________

Associate Professor (Dr. Muhammad Bilal Khurshid)

Military College of Engineering (MCE),

National University of Sciences and Technology (NUST)

Islamabad.

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Signature: ______________________________

Name of Supervisor: ____________________

Date:__________________________________

Signature (HOD): ________________________

Date:__________________________________

Signature (Dean/Principal): _______________

Date:__________________________________

DEDICATION

Dedicated to my beloved Prophet MUHAMMAD (S.A.W), my beloved Parents, Siblings, Friends and my Teachers, whose love, affection and continuous prayers for my success are the most precious asset of my life.

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LIST OF ABBREVIATIONS

ITS	Intelligent transportation system
MTS	Mass transit system
BRTS	Bus Rapid Transit System
ICT	Islamabad Capital Territory
PMBA	Punjab Metrobus Authority
BCR	Benefit-Cost Analysis
VTT	Value of Travel Time
US DOT	US Department of Transportation
CPI	Consumer Price Index
VOC	Vehicle Operating Cost
HCM	Highway Capacity Manual
LOS	Level of Service
MOE	Measure of Effectiveness
HCS	Highway Capacity Software
TRB	Transportation Research Board
PHF	Peak Hour Factor
PED	Price Elasticity of Demand
WHO	World Health Organization
NTRC	National Transportation Research Center
LRT	Light Rail Transit
MRT	Mono Rail Transit
CBD	Central Business District

FTA	US Federal Transit Authority
LCCA	Life Cycle Cost Analysis
ICT	Islamabad Capital Territory
CDA	Capital Development Authority
RDA	Rawalpindi Development Authority
MTS	Mass Transit System
NESPAK	National Engineering Services of Pakistan
VMS	Variable Message Signs
QS	Questionnaire Survey
WTP	Willingness to Pay
ISCP	Islamabad Safe City Project
TT	Travel Time
PBS	Pakistan Bureau of Statistics
ADT	Average Daily Traffic
MCC	Manually Classified Count
VMT	Vehicle Miles Travelled
RCF	Road Crash Fatalities
NRSS	National road safety secretariat
FHWA	US Federal Highway Authority
CRF	Crash Rate Factors
GDP	Gross Domestic Product
iRAP	International road assessment program
EIA	Environmental Impact Assessments

TCRP	Transit Cooperative Research Program
NPV	Net Present Value
RSL	Remaining Service Life
PW	Present Worth
CF	Cash Flow
O&M	Operation and Maintenance
BCR	Benefit to Cost Ratio

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ABSTRACT

Rapid urbanization and increased motorization are becoming the cause of severe congestion and unstable transportation system on streets and roads of metropolitan cities throughout the world. These not only affect the traffic, but have negative impacts on environment, economy and social well-being of people as well. To cope with such problems, a number of congestion mitigation strategies are available. Provision of mass transit system (MTS) has found to be a very successful strategy, under which the Bus Rapid Transit System (BRTS) has found to be an eminent one. A BRT provides fast, comfortable, economical and environmentally compatible mean of transportation. That's why BRTS is getting rapid popularity in developing countries. In Pakistan, the first of this kind of project was started in Lahore, the capital city of Punjab province. After successful implementation and a very positive response from the general public, it was decided to carry out such a project for the twin cities Islamabad-Rawalpindi. Islamabad is the capital of Pakistan with a population of 2 million, and the population of the twin cities is over 4.5 million inhabitants. The Islamabad-Rawalpindi BRTS operations were started in June 2015 and the project is successfully operational up till now. Now the point of concern is that whether this BRT project is fulfilling the needs and objectives, for which it was implemented. So, due to this reason there was a great need to carry out a research work to assess the BRT system. With this background this research study focused on the evaluation of BRTS Rawalpindi- Islamabad. The evaluation framework comprised of four main performance indicators which include transportation, environmental, safety and economic impacts. Transportation impacts evaluation was the key performance indicator and was further divided into eight sub-indicators. The methodology was the detailed analysis of each of these indictors. In the end, based on the results of analysis, it was concluded that the implementation of BRTS project has brought positive and beneficial impacts in terms of transportation aspects, road safety has been improved and environmentally hazardous emissions have reduced. Fare analysis revealed an inappropriate current fare level. The project was found economically not viable as the project costs exceed the project benefits. Economic analysis incorporating only the annual costs and benefits proved the project as economically viable. In the end recommendations were provided for the improvements in the project and the works to be done in future.

CHAPTER 1

1. INTRODUCTION

1.1. BACKGROUND

Metropolitan areas and big cities have always been the focus and concentration of major activities and have been the hub of national economy. Country's major economic activities take place in such big cities. Being the activity centers, these cities attract the people which result in complexities in the spatial urban structures. This flux of people towards big cities changes the socio-economy, land uses and demography of the urban areas. These changes disturb the overall settings of the city. Motorization and urbanization are the main indicators of this flux of people. These are becoming the cause of severe congestion and unstable transportation system on streets and roads of metropolitan cities throughout the world. These not only affect the traffic, but have negative impacts on environment, economy and social well-being of people as well. Traffic congestions cause delays, mental and physical disruption, increased vehicle operating costs, increased air and noise pollution and rapid deterioration of road surface etc. To cope with such problems, a number of congestion mitigation strategies are available. Some of these major strategies may include expansion of roadway capacity, introduction of intelligent transportation system (ITS), grade separated intersections, congestion pricing, introduction of mass transit programs and other traffic calming activities. The strategy relating to this study is the introduction of mass transit programs. Mass transit system (MTS), also called as public transport, is a shared service for the movement of passengers using different transportation vehicles such as wagons, buses, trams, rapid transit buses, metro rails and ferries etc. MTS is a relatively economical option for the people to opt.

In a developing country like Pakistan, people mainly rely on public transport for their daily transportation needs. Urban areas have a mix of traffic and are characterized by high population density, mixed land use pattern, higher ratio of non-motorized vehicles, shorter trip distances and poor public transport facility. Poor public transport facilities have lead the general public to use private vehicles and this has increased the motorization trend in the urban localities. This increased motorization has left the urban roads with higher traffic density and a congested urban road network system. Congestion on the roads results in long vehicle queues, increased travel time and slower speeds, which imply costs on the national economy and induce multiple adverse impacts on the urban inhabitants and disturbs the overall efficiency of the urban spatial structure (Rahane & Saharkar, 2014). Previously the Government authorities had been trying to improve the buses of the public transport to cater the congestion, but no satisfactory results had been extracted from these initiatives. Now it has been realized that the system can be well managed by improving both the buses as well as road infrastructure(Imran, 2009). So, an organized and managed Mass Transit System (MTS) has found to be a suitable option to be introduced. That's why Government has decided to initiate different mass transit services. Bus Rapid Transit System (BRTS) is an eminent option of mass transit initiated by the Government. A BRTS is a bus based transit service for the movement of general public and provides fast, economical, comfortable, affordable and environmentally compatible mean of transportation. A BRTS uses dedicated lanes for buses and gets priority at the intersections. That's why this system of rapid bus transit is getting rapid popularity in developing countries.

In Pakistan, the first of this kind of project was started in Lahore, the capital city of Punjab province. After successful implementation and a very positive response from the general public, it was then planned to carry out such a project for the twin cities Islamabad-Rawalpindi. Islamabad is the capital of Pakistan with a population of over 2 million, and the population of the twin cities is over 4.5 million inhabitants. Islamabad is the tenth largest city of Pakistan whereas the Rawalpindi is at the fourth position located in the Islamabad capital territory (ICT). The Islamabad-Rawalpindi metropolitan area is the third largest metropolitan area of the country with a growth rate of 4% per year. It is a well-organized international city divided into different sectors and zones and is considered as country's most developed city. Due to these reasons, the twin cities used to experience major intra and inter-city movement of people causing severe congestions on certain main roads. To cater congestion on roads, there had no organized and managed public transportation service. Keeping in view these points, it was then decided to carry out a bus rapid transit service for Islamabad-Rawalpindi. So, the construction work for the BRTS project started in February 2014 and was completed in June 2014.The Islamabad-Rawalpindi BRTS operations were then started in June 2015 and the project is successfully operational up till now. This BRTS project was aimed to provide a rapid, economical, comfortable, affordable and environmentally compatible mean of transportation to the public. It was also assumed that the

BRTS project will reduced the travel time of its commuters, reduce the congestion, minimize the air and noise pollution, decrease road crashes, reduce vehicle operating costs and provide a sustained public transport service. These were the goals and objectives of implementation of BRTS Rawalpindi-Islamabad.

Now the point of concern is that whether this BRTS project is fulfilling the goals and objectives, for which it was implemented. Also once such big projects like BRTS are planned and then implemented, it is always necessary to assess the project suitability and applicability. At the same time, it is also important to know that what would be the impacts of BRTS on the nation's economy, public safety, environment, and social well-being of the general public. On the other hand, Such a BRTS project was also planned and the implemented for Multan city and the operations of BRTS Multan has recently been started. The same kind of mass transit programs have also been proposed for other cities. So, all these important parameters necessitate the conduct of a detailed monitoring and evaluation program to assess and evaluate as well as help decision makers in deciding on the conduct and implementation of such other proposed, planned and continued projects. With this background and keeping the goals and objectives of BRTS project in mind, this research study was carried out to evaluate and assess the BRTS project. The focus of the study was to assess and evaluate the transportation impacts, safety impacts, environmental impacts and economic impacts of BRTS Rawalpindi-Islamabad. These were the key performance indicators of the research framework. Transportation impact analysis was the most importance performance indicator and was further divided into several sub-performance indicators. These sub-performance indicators have been discussed briefly in the next chapters.

1.2. PROBLEM STATEMENT

Islamabad is the capital city and is the most developed city of Pakistan with a population of almost 20 million inhabitants. The city is well planned and divided into different zones and sectors. The city is located adjacent to Rawalpindi city and both these cities are said to be as twin cities. Islamabad being the capital city has been the point of attraction for the people throughout the country. The city has a growth rate of 4% per year and experiences a major movement of people within the city and also people from the Rawalpindi area. These movements create several problems relating to traffic, environment, economy and safety. Road infrastructure and traffic system of the Islamabad is considered to the best in the country but the Rawalpindi is a congested city and relatively has a worse traffic and road infrastructure system. At the same time, the Rawalpindi-Islamabad metropolitan area had no organized and managed public transport system. The traditional public transport consists of Suzuki vans, buses, rickshaws and taxis. The condition of these vehicles is far below than any acceptable level and is characterized by humiliation, reckless driving, safety issues and increase trip times. According to Dr. Ghulam Abbas Anjum, a professor of transportation planning, it is alarming to state that Islamabad is among the very few capitals that have a worst urban transportation system. Unfortunately, a better public transport system had never been the priority of Government.

After looking at all these issues, the Federal and the Punjab Governments started thinking to resolve these issues. Hence, it was proposed to carry out a mass transit system (MTS) for the two cities Rawalpindi-Islamabad. So, a Bus Rapid Transit System (BRTS) was propped to be a suitable option of MTS. Very soon the construction and operations of BRTS started. Punjab Metrobus Authority (PMBA) looks after all the matters of BRTS and currently the project is operating successfully.

Now the problem arises that since a BRTS uses exclusive lanes for its buses and specialized bus and bus stations with a number of facilitates for the commuters, large public money was also invested for the initial construction and operations of the project. It is also claimed that the BRTS is a fast, comfortable, sustainable, safe, economical and environment friendly option of public transportation. Keeping in view the above points, it becomes very important to know that what benefits are being gained from such projects and what are their potential impacts on traffic, safety, economy and environment.

After successful implementation of BRTS Lahore and BRTS Rawalpindi-Islamabad, the operations of BRTS Multan have recently been started. At the same time, BRTS and other related public transport services are also proposed for some other big cities of the country. This shows a very rapid increasing trend of implementation of BRTS projects in the country.

Above discussed points validate the need to carry out a research study to evaluate the transportation, safety, environment and economic impacts of bus rapid transit system. So, in this research study, an effort has been made to assess and evaluate BRTS Rawalpindi-Islamabad and help agencies and decision makers on the feasibility of such proposed projects.

1.3. STUDY OBJECTIVES

The objectives of the research study are as follows:

- To assess the transportation, environmental, safety and economic impacts of BRTS.
- To determine whether the goals and objectives of BRTS project implementation achieved.
- To provide a basis for making decisions on similar kind of proposed and planned projects.
- To provide a detailed framework for the evaluation of Rawalpindi- Islamabad BRTS.
- To calculate an optimum fare for the BRTS.
- To identify problems and proffer recommendations for the implementation of such projects in future.

1.4. SCOPE OF WORK

Bus Rapid Transit System (BRTS) is a new concept in Pakistan. The first of this kind of project was started in Lahore, and very soon after the BRTS Lahore, the Rawalpindi-Islamabad BRTS was started. Same kind of projects are also proposed for some other big cities of the country. So, it shows a very rapid trend of implementation of BRTS projects in the country. At the same time, these are big projects and usually involve huge investments. So, it becomes very important to assess and evaluate such projects. There are different aspects and performance indicators of the evaluation of BRTS projects. In this study, the key performance indicators include transportation impacts, safety impacts, environmental impacts and economic impacts. Transportation impacts being the most important and main indicator, have been discussed and analyzed briefly and have been divided into different sub indicators. Safety, environmental and economic impacts have also been discussed and analyzed. There would have been social impacts, system sustainability and other performance indicators to be the part of evaluation framework but due to the scope of work, the research study has been limited to above discussed four key performance indicators only.

1.5. OVERVIEW OF STUDY APPROACH

To achieve the desired objectives of the study, a detailed methodology was developed, which consists of the following tasks;

- A comprehensive study of the previous researches carried out on the BRTS implementation, operation, monitoring and evaluation.
- Formation of research performance indicators.
- Formation of Questionnaire.
- Collection of data from the concerned departments and authorities.
- Collection of data from BRTS commuters on the basis of formulated questionnaire survey.
- Organizing the collected data using different statistical methods.
- Analyzing the collected data for each of the performance indicator.
- Extraction of results from the analyzed data.
- Conclusion of study and provision of recommendations.

Figure 1.1 shows the overall framework of the evaluation process and the methodology of the research work.

1.6. ORGANIZATION OF THESIS REPORT

For convenience and ease, the thesis report is divided into following five chapters.

The first chapter covers the brief introduction of research work carried out under this study, the problem statement, objectives and scope of this research work. It gives an overview of the problems for which this research study is being carried out.

The chapter two provides the brief review of research works carried out in the past regarding the bus rapid transit system, its implementation, operations, monitoring and evaluation. This chapter also gives description of different terminologies used in the research study.

The chapter three includes the research methodology portion of thesis report. This chapter discusses the overall framework of the conduct of research process, including project and study area description, formation and conduct of questionnaire survey, survey sampling and site selection, data collection processes and complete procedures for the analysis of the collected data.

Chapter four is the analysis and results chapter, which provides the detailed analysis of each of the performance indicators. The key performance indicators include transportation impacts, safety impacts, environmental impacts and economic impacts. Transportation impacts are further divided into sub-performance indicators which have been discussed briefly in this chapter. Based on the analyzed data, results for the each indicator have been extracted and discussed.

Chapter five of the thesis report concludes the overall work carried out in the research process. It includes conclusions and provides recommendations for the improvement of system and help decision makers in deciding the implementation of such projects in the future. It also recommends the future work need to be done in the evaluation process of BRT systems.

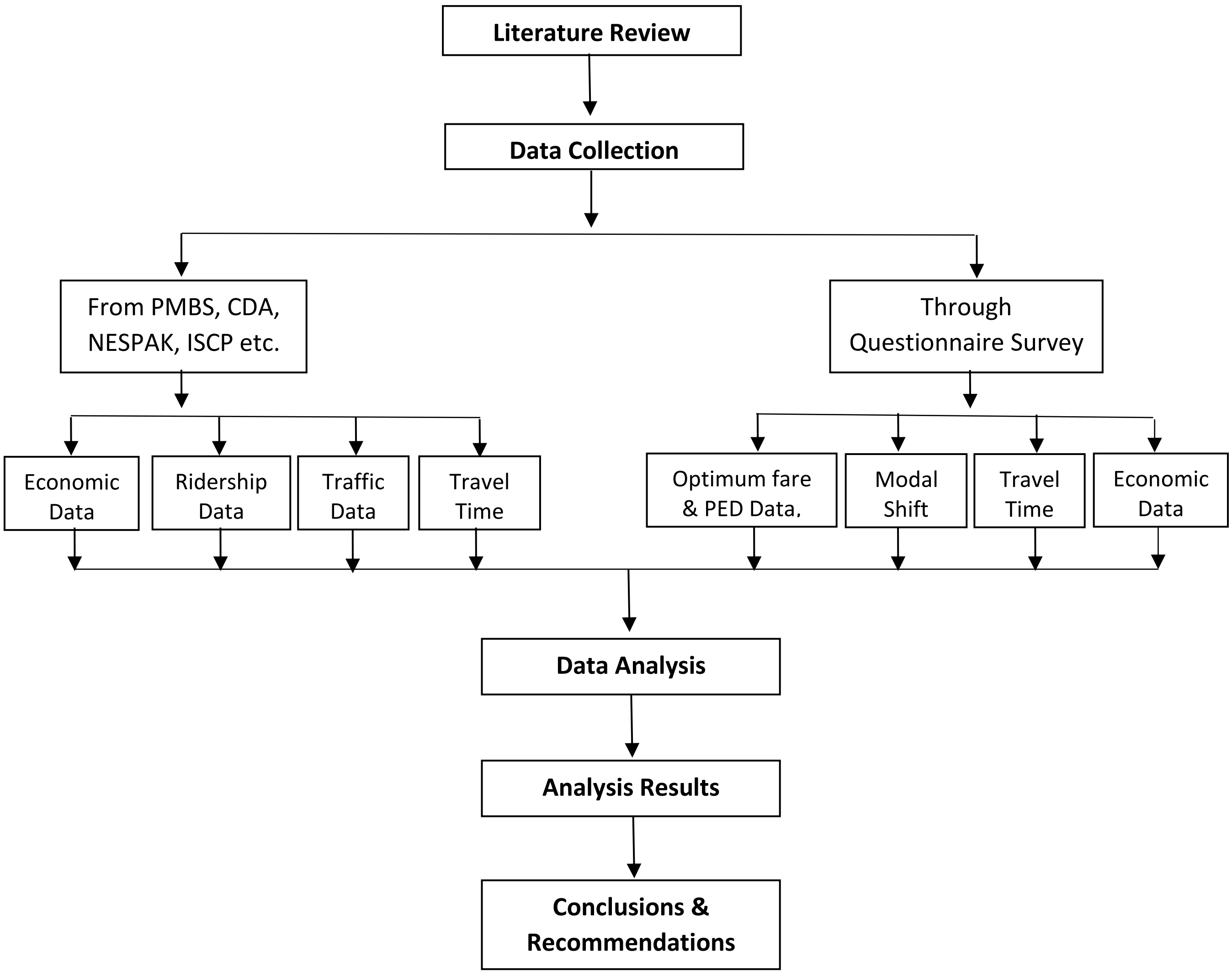

Figure 1.1: Organization of thesis report

CHAPTER 2

2. LITERATURE REVIEW

2.1. GENERAL

The concept of Bus Rapid Transit System (BRTS) is a new one in Pakistan. The first of this kind of project was initiated in Lahore, the capital city of Punjab province. This project got a good response from the public and currently operating successfully (Metrobus Concerns, 2014). Soon after the successful implementation and operation of BRTS Lahore, same kind of project was also initiated for Rawalpindi-Islamabad. After BRTS Rawalpindi-Islamabad, a BRTS project was launched for Multan city too. Such kinds of projects are also proposed for some other big cities of the country. This shows a very rapid increasing trend of implementation of BRTS projects in the country. So, it becomes important to assess and evaluate such projects to check whether these projects are valid and fulfilling the objectives for which these was initiated. As discussed above, BRTS is a new concept in Pakistan; no literature is available especially on the assessment and evaluation of such projects. Almost no work has been done to check the viability and applicability of BRTS projects. So, this research study provides a basis and an assessment tool in this regard.

A literature is anything that is available in the form of books, research papers, articles, journals, magazines or newspaper. A literature review is the complete explanation and summary of all the knowledge that is available in the literature on a particular topic. Literature review is one the most important and initial step while conducting any research study. It is the procedure through which a broader topic can be summarized to a narrower one and the procedure and framework to conduct a research study on this topic can be carried out while reviewing the literature.

The literature review chapter of this thesis report discusses the present and past works and studies carried out on the post implementation evaluation and assessment of public transportation system especially the case of bus rapid transit system. The discussion in the chapter also covers different methodologies that were used while conducting the studies to evaluate and assess the transportation, safety, environmental and economic impacts of BRTS and other related mass transit systems. The discussion in the chapter also provides insight into the literature that provides the methodologies to carry out sub-performance parameters.

2.2. IMPORTANT CONCEPTS AND TERMINOLOGIES

In this section, some of the important concepts and terminologies used in the research study has been discussed briefly. Terminology discussion has been categorized and done on the basis of key performance parameters.

2.2.1. Transportation Impacts

Transportation impacts evaluation is the key parameter among three other parameters than have been used in this study to carry out the post implementation evaluation process of BRTS Rawalpindi-Islamabad. Several important terminologies have been discussed in this section. For a better understanding, these terminologies have been briefly discussed in the below paragraphs.

2.2.1.1. Travel Time Saving

Travel time is the time spent while travelling from one point to another. This is one of the important parameters which is considered while choosing any mode, route or even a journey. The trip, route or the mode which has a reduced travel time, is mostly preferred to be chosen. Travel time saving is most often not quantified but it has substantial monetary benefits. In United Kingdom, the transportation Benefit-Cost Analysis (BCA) controls the 80% of the quantified benefits gained from the travel time savings (Mackie et al., 2001). Travel time is basically a function of two components; i.e. speed and distance. If the speed of vehicle and the distance are known, travel time can be estimated easily. Distance calculation is relatively an easy task but the speed calculation of vehicles is relatively a tough job, since there is always a mix of traffic in the road network system (HCS, 2000).

Kenneth (2012) states that it is hard to name an idea more broadly utilized as a part of transportation examination than the estimation of travel time. Its hypothetical importance and its exact estimation are key to travel request displaying, social cost investigation, valuing choices, extend assessment, and the assessment of numerous open strategies.

Gunn (2000) discusses that the time could not be purchased, sold or possessed nor exchanged to any other person yet to approve its significance it is accepted that the time spared in travelling can be used in some other helpful activity. Same is the situation with losses.

According to a research study Victoria Transport PI (2017), travel time is one of the biggest classifications of transport expenses, and time investment funds are regularly the best expected advantage of transport upgrading projects. Elements, for example, commuting relief and travel unwavering quality can be evaluated by modifying travel time cost values. On normal individuals give 60-90 minutes a day to travelling. A great many people appear to appreciate a certain measure of individual go, around 30 minutes per day, and dislike dedicating more 90 minutes day. Investing unnecessary measures of energy in travel (especially during the congested travel times) appears to decrease life gratification.

While talking about Value of Travel Time (VTT), in a memorandum to Secretarial Officers Modal Administrators, US Department of Transportation (US DOT), the estimation of decreasing travel time communicates three standards. To start with, time spared from travel could be committed to generation, yielding a financial advantage to either explorers or their bosses. Second, it could be spent in diversion or other pleasant or vital exercises for which people will pay. Third, the states of go amid part or the majority of an excursion might be disagreeable and include strain, weakness, or distress. Lessening the time spent while presented to such conditions might be more significant than sparing time on more agreeable segments of the outing (Belenky et al., 2011).

2.2.1.2. Consumer Price Index (CPI)

A Consumer Price Index (CPI) measures changes in the value level of buyer products and enterprises bought by households. The CPI is a statistical appraise developed utilizing the costs of an example of agent things whose costs are gathered periodically". By utilizing CPI, cost of a thing can be moved from one year to another year for investigation and analysis purpose.

2.2.1.3. Vehicle Operating Cost (VOC)

Vehicle operating costs allude to costs that fluctuate with vehicle utilization, including fuel, tires, support, repairs, and mileage-subordinate devaluation costs. Projects that change vehicle miles voyaged, speed and delay, roadway surfaces, or roadway geometry may influence explorer's vehicle working costs, which ought to be considered in an advantage cost investigation (Hamilton & A. Booz, 1999).

Litman (2009) discussed that Vehicle Costs incorporate direct client costs to claim and utilize private vehicles. These demonstrate the investment funds that outcome from lessened vehicle possession and utilize. These can be separated into fixed (additionally called possession or time-based, which are unaffected by the sum a vehicle is driven like Vehicle ownership cost, vehicle registration fee, insurance fee etc.) and variable (likewise called working, negligible or incremental, which increment with vehicle mileage, such as fuel, vehicle repair and maintenance, tire wear and tear etc.). A few expenses for the most part sorted as fixed, for example, devaluation and protection, really increment with vehicle mileage.

VOC is increased as the congestion increases. The congestion causes the vehicle to reduce their speed. This reduced speed also causes increased VOC. Sinha & Labi, (2011) discussed the relationship between vehicle depreciation rate and average vehicle speed as a function of vehicle class. As the average speed of the vehicle increases, the rate of vehicle depreciation decreases. This relationship has been shown by the below figure 2.1.

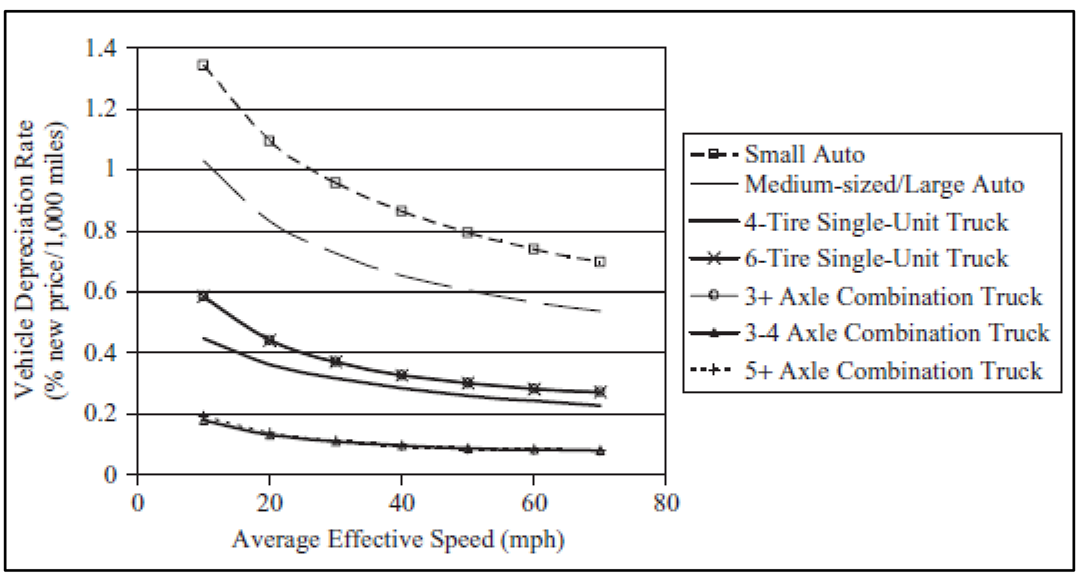

Figure 2.1: Depreciation rate by speed for straight sections (FHWA, 2002)

For area wide or corridor level undertakings including multimodal frameworks, a change in any piece of the framework can influence VOCs of alternate parts or different modes. For instance, benefit change in suburbanite rail or arrangement of a transport quick travel along a hallway can influence the level of administration on roadway offices in a similar passage on the grounds that the move of a few voyagers from car to travel would prompt enhanced interstate level of administration because of diminished clog and in this way, bring down or lessening the vehicle operating expenses at the highway segment (Sinha & Labi, 2011).

As discussed earlier, VOC is a very important element among the overall costs incurred during the travelling. There are a number of factors that affects VOC. For a better and easy understanding, Sinha & Labi (2011), in their book "Transportation Decision Making, Principles of Project Evaluation and Programming" briefly discussed the factors that affect the VOCs. This has been shown schematically in the below figure 2.2.

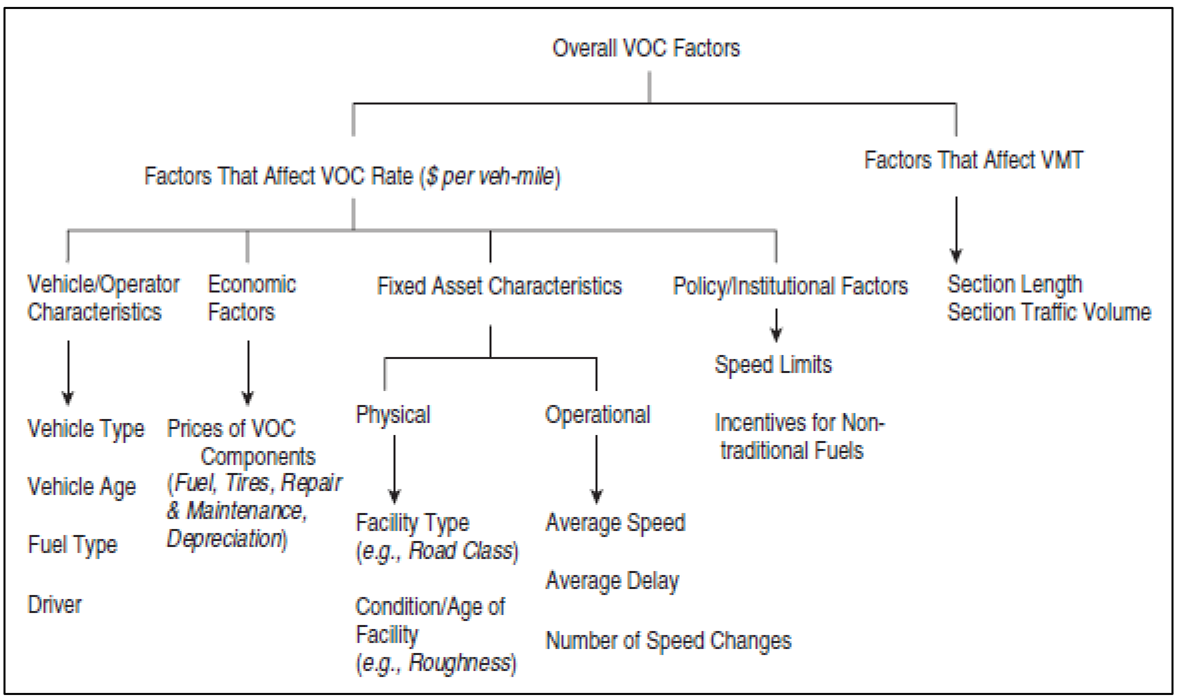

Figure 2.2: Factors affecting VOC (Sinha & Labi, 2011)

To bring the vehicle operating cost (VOC) into monetary terms, Hepburn (1994) presented a model. This model is for urban roadways and incorporates the sum of four VOC elements which include tire, fuel, vehicle depreciation and maintenance. The model is especially helpful for assessing VOC effects of transportation interventions that for the most part yield an adjustment in operating speeds or arrangements that create a shift in vehicle class appropriation. The Hepburn model is as follows:

For "low" average travel speeds (<50 mph) :

$$\text{VOC} = C + \frac{D}{S}$$

For "high" average travel speeds (>50 mph) :

$$\text{VOC} = a_0 - a_1 S + a_2 S^2$$

Where VOC is in cents/mile, S is the speed in (mph) and C, D, a_0, a_1, and a_2 are coefficients which are the functions of vehicle class.

Table 2.1: Parameters for Hepburn's VOC-Speed model (Sinha & Labi, 2011)

Vehicle Type	C	D	a_0	a_1	a_2
Small automobile	24.8	45.5	27.2	0.035	0.00021
Medium-sized automobile	28.5	95.3	33.5	0.058	0.00029
Large automobile	29.8	163.4	38.1	0.093	0.00033

2.2.1.4. Capacity and Level of Service (LOS)

Highway Capacity Manual (HCM 2000) defines the capacity as "the maximum hourly rate at which persons or vehicles can be reasonably expected to traverse a point or a uniform segment of a lane or roadway during a given time period under prevailing roadway, traffic and control conditions". The capacity of highway depends on certain conditions which include traffic condition (Traffic mix and traffic stream characteristics), Roadway condition (road geometry) and control condition (signs and signals) (Mathew & Rao, 2006).

Highway Capacity Manual gives the definition of Level of Service as "the Level of Service (LOS) is a quality measure describing operational conditions within a traffic stream, generally in terms of such service measures such as speed and travel time, freedom to maneuver, traffic interruptions, comfort and convenience". (HCM, 2000) defines six LOS levels, from LOS-A to LOS-F, where LOS-A describes the best traffic operating condition, while LOS-F designates the worst. These criteria for LOS determination for basic freeway sections and multilane highways have been shown in Table 2.2 (Roess et al., 2011b).

Table 2.2: Measure of Effectiveness defining LOS (HCM, 2000)

Type of Flow	Type of Facility	Measure of Effectiveness
Uninterrupted Flow	Freeways	
	Basic sections	Density (pc/mi/ln)
	Weaving areas	Density (pc/mi/ln)
	Ramp junctions	Density (pc/mi/ln)
	Multilane Highways	Density (pc/mi/ln)
	Two-Lane Highways	Average Travel Speed (mi/h)
		Percent Time Spent Following (%)
Interrupted Flow	Signalized Intersections	Control Delay (s/veh)
	Unsignalized Intersections	Control Delay (s/veh)
	Urban Streets	Average Travel Speed (mi/h)
	Transit	Service Frequency (veh/day)
		Service Headway (min)
		Passengers/Seat
	Pedestrians	Space (ft^2/ped)
	Bicycles	Frequency of (Conflicting) Events (events k)

In HCM (2000), the LOS has been defined in terms of particular Measure of Effectiveness (MOE) for different type of facilities (Roess et al., 2011). This has been shown in the table 2.3.

Table 2.3: Measure of Effectiveness defining LOS (HCM, 2000)

Type of Flow	Type of Facility	Measure of Effectiveness
Uninterrupted Flow	Freeways	
	Basic sections	Density (pc/mi/ln)
	Weaving areas	Density (pc/mi/ln)
	Ramp junctions	Density (pc/mi/ln)
	Multilane Highways	Density (pc/mi/ln)
	Two-Lane Highways	Average Travel Speed (mi/h)
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Interrupted Flow	Signalized Intersections	Control Delay (s/veh)
	Unsignalized Intersections	Control Delay (s/veh)
	Urban Streets	Average Travel Speed (mi/h)
	Transit	Service Frequency (veh/day)
		Service Headway (min)
		Passengers/Seat
	Pedestrians	Space (ft^2/ped)
	Bicycles	Frequency of (Conflicting) Events (events k)

There are certain factors that affect the LOS of a highway segment (Mathew & Rao, 2006). These factors include:

- Travel time and Speed of the vehicle.
- Road geometry (Lane width, lateral clearance, median type etc.).
- Traffic interruptions (Signals).
- Driver’s comfort and convenience.
- Freedom to maneuver.
- Operating cost.

2.2.1.5. Highway Capacity Software (HCS)

Highway Capacity Software (HCS 2000) is a traffic engineering software based on Highway Capacity Manual (HCM 2000). It was originally developed by US Federal Highway Authority (FHWA) in 1986. This software follows the procedures and techniques given in Highway Capacity Manual (HCM), published by Transportation Research Board (TRB) and can be used for analyzing capacity and determining LOS for signalized Intersections, un-signalized Intersections, urban streets (arterials), freeways, multilane highways, two-lane highways, weaving areas, ramp junctions and transit services. Previous versions of HCS had lesser provisions for capacity and LOS analysis but the later updated versions provide a more instinctive and collaborative tool for the analysis of signalized intersections (Center, 1998).

For the analysis of urban arterials, HCS requires the data of peak hour traffic volume, peak hour factor (PHF), peak 15 minute volume, road geometry, free flow speed, and adjustment factors for highway median, lateral clearance, Access points, presence of heavy vehicles etc. These adjustment factors can be determined from HCM.

2.2.1.6. Modal Shift

Modal shift is when there are one or more modes in competition and people prefer the best mode chosen on the bases of different parameters, such as economy, reduced travel time, comfort, reliability etc. It is the percentage of people transferring from one mode to another due to an intervention in transportation system. Mathew & Rao (2006) discussed the factors that influence the choice of a transportation mode. Some of these factors include:

- Availability of private vehicle.
- Socio-economic characteristics of the traveler.
- Trip purpose.
- Time of the trip to undertake the journey.
- Total travel time by the respective modes.
- Total travel cost/fare.
- Parking availability.
- Comfort and convenience provided by the mode.

- Safety and security concerns.

Selection of any of the mode depends on the above factors. Commuters usually prefer the mode that is more suitable for them keeping in view the above factors (Mathew & Rao, 2006).

According to Mane et al., (2015) Modal shift analysis is among one of the primary indicators for predicting the shifting nature of travelers from their previous transportation mode to the newly adopted mode of transportation. A public transport service with exclusive bus lane has the capability to induce the people from conventional public transport or private vehicles. In a research study in china, Wang et al., (2012) discussed that the modal shift to BRTS from private vehicles has increased significantly, since the introduction and operation of BRTS in Chinese cities. This modal shift is because the fact that the BRTS has reduced travel time, reliability and trip distance variables. Further Nurdden et al., (2007) argued that gender, age, socio-economic characteristics, travel time and travel fare are also the factors that influence the modal shift from private vehicles to public transportation services. Out of these factors; in vehicle travel time, out of vehicle travel time (distance to public transportation service) and travel cost are the encouraging factors for the people to use the public transport.

Modal shift to a dedicated lane bus transport system also helps in a safer transportation system. Nurdden et al., (2007) reported that in Malaysia, the increasing number in the registration of private vehicles has resulted in an increased number of deaths and injuries to their users. This safety concern was addressed by the Govt. and different strategies were put forward to cope with this problem. Hence, it was ultimately decided to divert the people to a safer mode of transportation i.e. public transport.

On the contrary, Davison & Knowles (2006) indicated that subsidies on private vehicles and unfamiliarity to public transport specially BRTS has put negative impacts on the applicability of BRTS and people switch toward private vehicles and other modes from public transport (BRTS).

2.2.1.7. Ridership Demand

Transportation demand is the number of trips that people make to overcome their transportation needs and complete their socio-economic activities. The demand for any particular transportation service or facility depends on the socio-economic characteristics of the people as well as the physical transportation facilities, Operational conditions, service attributes and the related government policies. For the estimation of transportation demand, the most common variable is trip price/fare. Transportation demand is very sensitive to trip price. As the trip price increases, the demand falls. This is called “Law of Demand” (Economic time, 2017).

The first mathematical function for the law of demand was provided by (Cournot, 1843). This function is given as under:

$$D = f\ (p)$$

Under normal conditions; $f\ (p) < 0$.

Cournot (1843) also explained this relation graphically as provided in figure 2.3:

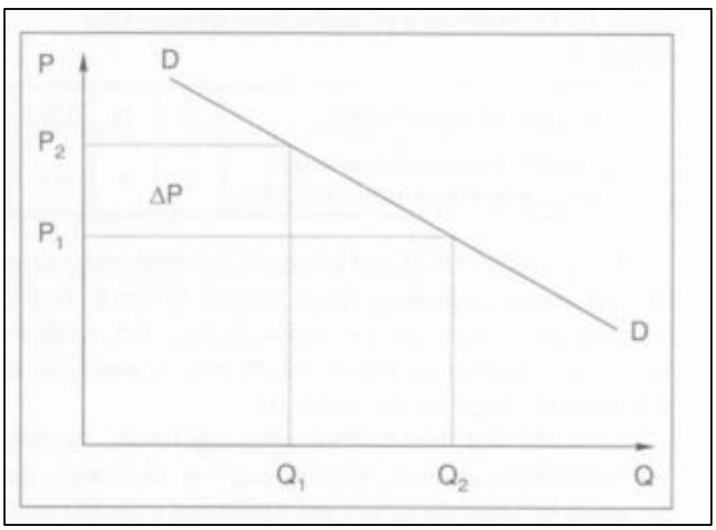

Figure 2.3: Demand Curve (Cournot, 1843)

From the above graph, it can be interpreted that the quantity demanded for a particular service or goods is the function of price (fare), and it follows a falling character, since it is clear that the price is partial derivation of function of (p) less than zero. It can be further interpreted that when the price increases from P_1 to $P_{2,}$ the demand decreases from the quantity Q_1 to Q_2. This describes an inverse relation between the price and quantity demanded (Cournot, 1843)

Ridership demand depends upon different factors. These factors include price (fare) of transportation service, user preferences, income of the user, services being provided by the system and other related factors (Perić, 2001). Wardman (1997) further discussed some factors that influence the travel demand, including population density, household growth, employment and employers, workers flow, income and other socio-economic characteristics of the people living in that region (Wardman, 1997).

2.2.1.8. Optimum Fare

A public transport facility such as BRTS, MRT or any such facility is built to provide economical, comfortable, reliable and environment friendly mean of transport. This is a service provided by the Government to its public, that's why government agrees to provide a subsidy for this service or facility. Also, it is a general practice throughout the world that the public transport facilities are mostly subsidized. According to Parry (2009), Traveler fares for public transportation are in many places intensely subsidized. Over the 20 biggest transportation systems in the United States (positioned by traveler miles), the subsidy, as calculated by the contrast between operating expenses and traveler toll incomes, ranges from 29 to 89 percent of operating expenses for rail and from 57 to 89 percent for bus transport. Laube and Kenworthy also discussed similar sort of pattern across the other urban transportation systems in some other developed countries (Parry, I. W., & Small, 2009). The following table 2.4 shows the traveler's fare subsidy provided by twenty largest transit authorities of USA.

Table2.4: Passenger Fare Subsidies for 20 Largest transit Authorities of US (FTA, 2003)

	Fare subsidy (% of operating cost)			Passenger miles		
	rail	bus	combined	total, million	% rail	%bus
MTA New York City Transit, Brooklyn, NY	29	59	41	9,451	83	17
New Jersey Transit Corporation, Newark, NJ	50	57	53	2,548	64	36
MTA Long Island Rail Road/Bus, Jamaica, NY	53	61	53	2,302	93	7
Metro-North Commuter Railroad Co., New York, NY	40	n/a	40	2,059	100	0
Washington Metrop. Area Transit Authority, Washington, DC	40	75	55	1,899	76	24
Massachusetts Bay Transportation Authority, Boston, MA	57	79	64	1,838	82	18
Los Angeles County Metrop. Transp. Authority, Los Angeles, CA	78	72	73	1,839	21	79
Chicago Transit Authority, Chicago, IL	59	64	62	1,814	58	42
Northeast Illinois Regional Commuter Railroad Corp., Chicago, IL	56	n/a	56	1,506	100	0
Southeastern Pennsylvania Transp. Authority, Philadelphia, PA	50	62	57	1,354	65	35
San Francisco Bay Area Rapid Transit District, Oakland, CA	42	n/a	42	1,148	100	0
Metropolitan Atlanta Rapid Transit Authority, Atlanta, GA	67	71	69	722	68	32
Maryland Transit Administration, Baltimore, MD	72	74	73	631	47	53
King County Dept. of Transp. - Metro Transit Division, Seattle, WA	n/a	82	82	433	0	100
Metrop. Transit Authority of Harris County, Texas, Houston, TX	n/a	82	82	417	0	100
Tri-County Metrop. Transp. District of Oregon, Portland, OR	35	89	76	407	42	58
Miami-Dade Transit, Miami, FL	85	75	77	389	28	72
Dallas Area Rapid Transit, Dallas, TX	89	87	88	385	36	64
Denver Regional Transportation District, Denver, CO	63	80	79	371	12	88
Port Authority of Allegheny County, Pittsburgh, PA	81	73	75	305	10	90
Average or total (unweighted)	**58**	**73**	**65**	**31,819**	**54**	**46**
Average (weighted by passenger miles)	**44**	**69**	**54**		**72**	**28**

A higher fare level discourages the people to travel; resultantly a reduced ridership is experienced. Similarly a lower fare level maximizes the subsidy, which overburdens the government. So an optimum fare level provides a balance so that the ridership demand doesn't fell down considerably as well as the government provided subsidy is also minimized. Paulley (2006) argued that fares are the basics for the operations of public transport since they develop the main source of income to client. Generally, when the fare is increased, the ridership gets decreased. Whether the net revenue increases or decreases as a result of increase in the fare, it depends on the basic relationship between fare and ridership which is described by the "demand curve". The demand curve has been shown in figure 2.4. This is usually described through the concept of "Elasticity" (Paulley, 2006). The concept of elasticity will be explained briefly in the coming sections of the chapter.

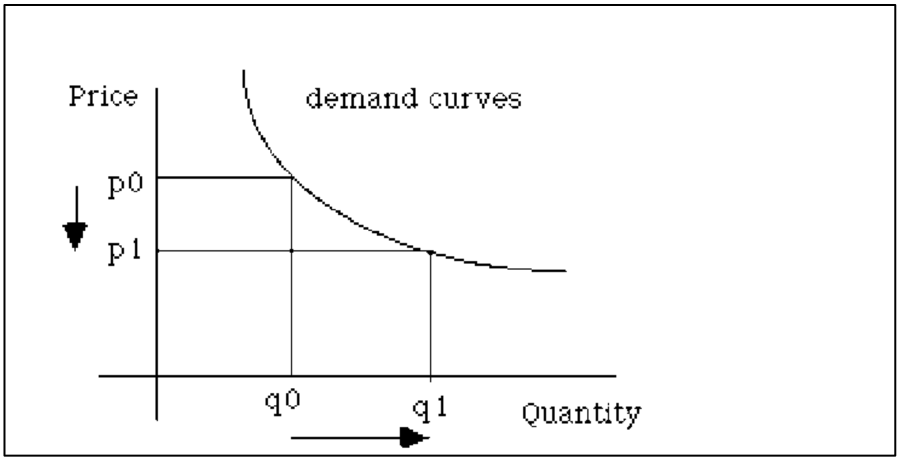

Figure 2.4: Demand Curve (Paulley, 2006)

The above figure illustrates that when the price is raised from p_1 to p_o, the quantity reduced from q_1 to q_o. So an optimum fare level needs to be calculated to give a balance between the two parameters i.e. price (p) and demand (q).

2.2.1.9. Price Elasticity of Demand (PED)

The "law of demand" is one of the famous laws in the economics. This law states that" higher the price of a good or service, lower will be its consumers or buyers". To check the behavior of users, the economists use different methodologies to assess and evaluate the sensitivity of users or consumers to the price of that good or service (P. L. Anderson et al., 1997). Furthermore, P. L. Anderson et al., (1997) stated that the most common and widely used measure of sensitivity of users or consumers is known to be as Price Elasticity of Demand (PED). It is basically the proportionate change in demand for a unit change in fare or the price. Price elasticity of demand is used to determine the relationship between the percent changes in demand with respect to a percent change in its price. This can be further elaborated as that what is the sensitivity of demand when the price is changed by one unit (Sinha & Labi, 2011). This is a check to the price sensitivity of any good or service. Mathematically it can be stated as;

Price elasticity of demand = % change in quantity demanded / % change in price

$$E_d = \frac{\%\_Change\_in\_demand}{\%\_Change\_in\_X}$$

$$E_d = \frac{Change\_in\_demand / Original\_demand}{Change\_in\_x / Original\_value\_of\_x}$$

$$E_d = \frac{\partial V / V}{\partial x / x} = (\frac{x}{V})(\frac{\partial V}{\partial x})$$

A demand model may take any of mathematical model. Below table 2.5 shows different elasticity functions for certain mathematical forms of demand model. Sinha & Labi (2011) argued that different factors affect the demand elasticities such as trip purpose, trip time, trip mode, length of trip and characteristics of trip maker.

Table2.5: Elasticity Functions for Standard Mathematical Forms of Aggregate Demand (Sinha & Labi, 2011)

	Elasticity Function: $(x/V)(\partial V/\partial x)$
Linear	
$V = \alpha + \beta x$	$\frac{\beta x}{V} = \frac{1}{1 + (\alpha/\beta x)}$
Product	
$V = \alpha x^{\beta}$	$e = \beta$
Exponential	
$V = \alpha e^{\beta x}$	$e = \beta x$
Logistic	
$V = \frac{\alpha}{1 + \gamma e^{\beta x}}$	$\left(1 - \frac{V}{\alpha}\right) = -\frac{\beta_{\gamma} x e^{\beta x}}{1 + \gamma e^{\beta x}}$
Logistic-product	
$V = \frac{\alpha}{1 + \gamma^{x\beta}}$	$\left(1 - \frac{V}{\alpha}\right) = -\frac{\beta \gamma x^{\beta}}{1 + \gamma x^{\beta}}$

A good or service is said to be perfectly inelastic when its price elasticity of demand is equal to zero. It means that the changing the price does not affect the demand. A value of PED between zero and one shows that the demand is inelastic, which means that any change in price or fare produces a small change in demand. And any value of PED greater than one indicates that the demand for that good or service is perfectly elastic, which can be elaborated as a small change in price or fare produces a major change in its quantity demanded (Sinha & Labi, 2011). This complete phenomenon can be understood easily by the figure 2.5 as shown below:

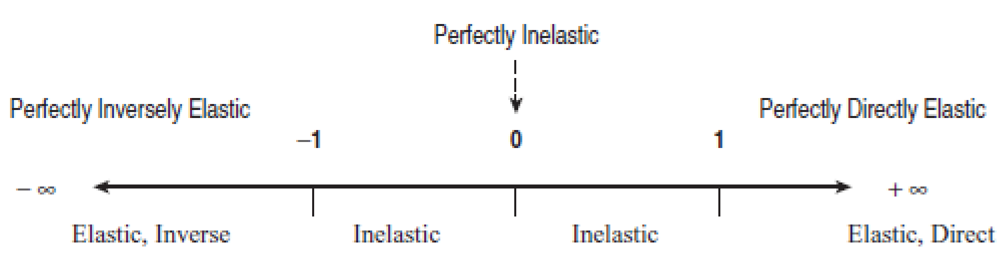

Figure 3.6 Elastic and inelastic regions.

Figure 2.5: Elastic & Inelastic regions (Sinha & Labi, 2011)

The travel elasticity value used in any condition depends upon the different attributes such as existing demand level, type of trip, area and location characteristics, existing elasticity level and other socio-economic features. E.g. individuals who depend on public transit services for daily commuting needs are generally less sensitive if the transit fare or any other attributes of the public transit changes. According to Litman (2005), as the drivers, vehicles, transportation options and per capita increase, the transit elasticity value are also expected to increase. Transit elasticity values which have been determined from the studies decades ago may mis-guide the results because there are many factors which have been changed in the current years. These temporal changes may be percentage of people dependent on public transit, socio-economic characteristics and vehicle ownership etc. For example, (Dargay and Gately) found that around 30% of response of commuters due to price changes occurs within one year and apparently 100 % occurs within 13 years.

2.2.1.10. Capacity Analysis

According to S. K. Jaiswal (2010), capacity of a BRTS bus can be defined as the maximum number of passengers that a bus can take. And the capacity of the entire system is the maximum number of passengers that can travel in the buses in unit time. Moreover, Reilly & Levinson (2011) in their study determined that integrated public transit system like BRTS have proved to be an economical, affordable, reliable and environmentally compatible mean of transportation. The practical capacity of these systems range from 10,000 to 35,000 passengers per hour, depending upon the number of lanes provided for the buses. Currently there are over 50 developing cities where integrated transit systems such as Bus rapid Transit Systems (BRTS's) have been implemented successfully.

Transit capacity includes both the movement of people as well as the vehicle movements. It can be defined as the maximum number of people that can be moved from one place to another for a certain period of time under prevailing operating circumstances without causing much delay or an unfair condition (Reilly & Levinson, 2011).

Different developing cities have adopted BRT systems and their systems are operating successfully. Below table 2.6 shows the peak hour ridership by high capacity BRTS buses for different cities of the world (Reilly & Levinson, 2011).

Table 2.6: Hourly Passenger Volumes for High-capacity Buses (Reilly & Levinson, 2011)

Region	City	Peak Volume (pphpd)*
Asia	Ahmedabad	3,000
	Beijing	4,100
	Guanzhou	25,000
	Hangzhou	6,600
	Jakarta	4,000
	Jinan	3,600
	Seoul	6,700
Latin America	Belo Horizonte	16,000
	Bogota	45,000
	Curitiba	14,000
	Mexico City	9,000
	Porto Alegre	26,100
	Sao Paulo	20,000
	Quito	8,000
Africa	Lagos	10,000

*pphpd – passengers per hour per direction

There is a significant variation in the capacity, configuration and size of transit buses in different cities of the world. When considering BRT services, only full size transit buses are suitable. The below table 2.7 shows seating capacity and other characteristics for a range of transit buses used in Pakistan and other Asian cities (Reilly & Levinson, 2011).

Table 2.7: Typical Bus models & Characteristics in Asia (Reilly & Levinson, 2011)

Manufacturer	Model	Floor Height	Length (m)	Seating Capacity	Standing* Capacity
Ashok Leyland	222	High	10.9	50	20
	Articulated bus	High	16	52	20
Volvo	8700	Low	12	40	N/A
	8700	Low	13.5	45	N/A
	8700	Low	15	53	N/A
	8700	High	12	53	N/A
	8700	High	13.5	55	N/A
Tata	STAR ULF	Ultra low	12	27	35
	STAR LF	Low	12	44	35

* Manufacturer's estimate

In the same study, the authors presented a general applicable approach to determine the capacity of a transit bus, which is as follows:

$$Vehicle\ Capacity\ = No.of\ seats + \frac{Area\ available\ for\ standing}{Area\ per\ standee}$$

This is how the maximum capacity of transit bus can be determined.

Generally, the number of standees can also be determined from the below shown table 2.8 (Reilly & Levinson, 2011).

Table 2.8: Urban rail & Bus Loading Standards (Reilly & Levinson, 2011)

Place of Application	Typical Number of Standees per Square Meter
EU	4-5
US, Canada	3-4
Latin America BRT	6-8
Asia	8-10

2.2.2. Safety Impacts

Transportation of people and goods takes place through different means, which predominantly include roadways and highways, railways, airway, waterway and pipe-ways. Out of these roadways contribute the major proportion and has the highest percentage to carry people and goods from one place to another (Solomon et al., 1988).

Road traffic problems and related crashes put a negative mark to roadway traffic. A crash is the basic unit to measure transportation safety and can be defined as the "collision of a transportation vehicle with another vehicle or with an object. Crashes because of road traffic have become a serious concern throughout the world and are being accounted as world's largest general public health problem and injury prevention issue. The problem becomes more complicated when these health issues involve victims who are overwhelmingly healthier before the occurrence of crash. World Health Organization (WHO) reports that each year more than one Million people suffer to death globally due to fatal road crashes and more than this suffer from other non-fatal injuries (WHO, 2002). A fatal is the highest level casualty. In another report by WHO, annually 1.2 million people were killed and around 50 million people were injured due to road crashes throughout the world (WHO, 2004). Below tables 2.9 and 2.10 show the mortality rates characterized by age group, sex and income level on the basis of WHO regions.

Table 2.9: Mortality rates caused by road traffic injuries by sex and age group (WHO Global Burdens of Disease Project, 2002)

Estimated mortality caused by road traffic injury,[a] by sex, age group, WHO region and income level, 2002

Absolute numbers[b]

WHO region	Income level	Total[c]	Males						
			All ages	0—4 years	5—14 years	15—29 years	30—44 years	45—59 years	≥60 years
All	all	1 183 492	862 784	27 808	82 337	242 584	222 286	160 518	127 251
	high	117 504	83 839	953	2 157	27 443	19 632	14 993	18 661
	low/middle	1 065 988	778 945	26 855	80 179	215 141	202 654	145 526	108 590
African Region[d]	low/middle	190 191	131 240	10 488	39 116	25 829	26 526	17 458	11 823
Region of the Americas	all	133 783	100 378	1 950	4 613	33 772	26 675	18 436	14 933
	high	47 865	32 610	455	999	11 369	8 010	6 029	5 747
	low/middle	85 918	67 768	1 495	3 614	22 403	18 665	12 407	9 185
South-East Asia Region[d]	low/middle	296 141	225 363	3 790	15 082	64 119	65 311	45 383	31 678
European Region	all	127 129	94 529	893	3 084	29 559	25 536	18 995	16 462
	high	43 902	32 753	203	697	11 536	7 847	5 204	7 265
	low/middle	83 227	61 775	690	2 387	18 023	17 689	13 790	9 197
Eastern Mediterranean Region	all	132 207	96 020	7 127	11 887	25 201	19 663	15 916	16 226
	high	1 425	1 196	61	49	390	359	239	98
	low/middle	130 782	94 824	7 066	11 838	24 811	19 304	15 677	16 128
Western Pacific Region	all	304 042	215 253	3 560	8 555	64 104	58 574	44 330	36 129
	high	24 313	17 279	234	412	4 148	3 416	3 520	5 550
	low/middle	279 729	197 974	3 326	8 143	59 957	55 159	40 810	30 579

Table 2.10: Mortality rates per 100,000 Population (WHO Global Burdens of Disease Project, 2002)

Rate per 100 000 population

WHO region	Income level	Total[b,c]	Males						
			All ages[a]	0—4 years	5—14 years	15—29 years	30—44 years	45—59 years	≥60 years
All	all	19.0	27.6	8.8	13.2	29.7	33.5	37.6	45.1
	high	12.6	18.3	3.4	3.6	28.8	18.3	16.7	23.7
	low/middle	20.2	29.2	9.3	14.3	29.9	36.5	43.2	53.3
African Region[d]	low/middle	28.3	39.3	18.6	42.6	27.2	53.4	65.7	81.9
Region of the Americas	all	15.7	23.9	4.9	5.8	31.2	29.8	29.9	35.2
	high	14.8	20.5	4.0	4.2	33.5	22.0	20.0	25.0
	low/middle	16.2	25.9	5.3	6.5	30.2	35.1	39.4	47.4
South-East Asia Region[d]	low/middle	18.6	27.7	4.1	8.5	28.6	39.3	46.9	55.7
European Region	all	14.5	22.2	3.5	5.1	30.0	26.1	24.8	25.0
	high	11.0	16.8	1.9	3.0	29.8	16.8	13.6	19.4
	low/middle	17.4	26.9	4.6	6.5	30.1	34.5	35.9	32.3
Eastern Mediterranean Region	all	26.3	37.4	20.3	18.7	34.2	43.3	62.9	116.3
	high	19.0	26.2	17.9	7.5	38.4	21.7	32.1	59.1
	low/middle	26.4	37.6	20.3	18.8	34.2	44.1	63.9	117.0
Western Pacific Region	all	17.7	24.6	5.3	5.7	29.6	27.4	31.8	40.8
	high	12.0	17.3	4.2	3.5	19.1	15.1	17.1	31.0
	low/middle	18.5	25.5	5.4	5.9	30.8	28.8	34.3	43.3

Source: WHO Global Burden of Disease project, 2002, Version 1.

[a] Road traffic injury = ICD-10 V01–V04, V06, V09–V80, V87, V89, V99 (ICD-9 E810–E819, E826–E829, E929.0).

[b] Any apparent discrepancies in total sums are a result of rounding.

[c] Combined total for males and females.

[d] No high-income countries in the region.

Following figure 2.6 describes the number of road traffic crash fatalities using different modes in European Union (EU) countries and United States (US).

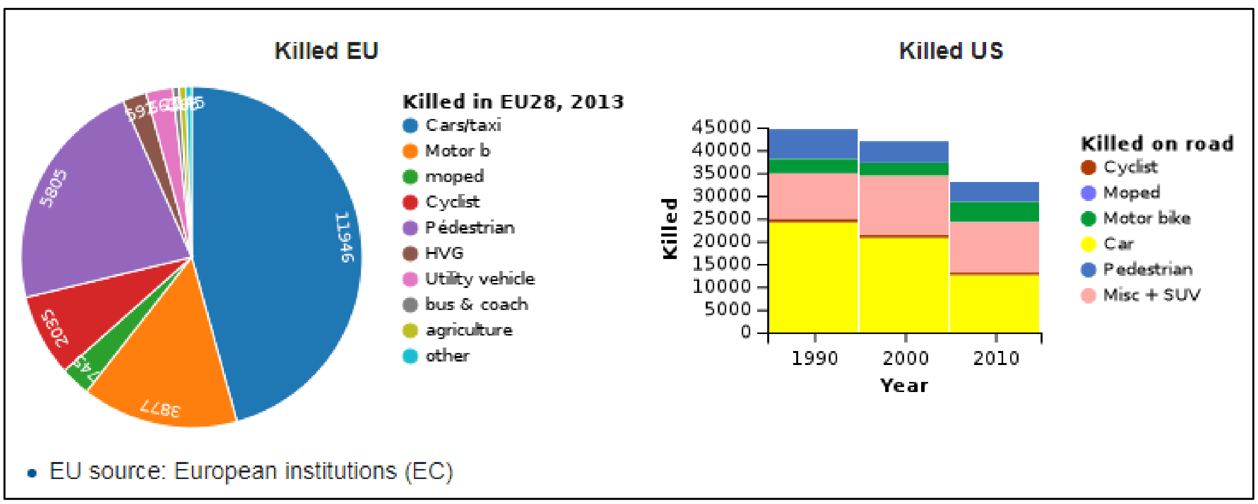

Figure 2.6: Road traffic crash fatalities EU and US (European Institutions, OECD, 2015)

National Transportation Research Center (NTRC) reports that each year around 1.4 million people are killed as a result of road traffic crashes in Pakistan (NTRC, 1999). Road crash fatalities are the second leading cause of disability and fifth leading cause of premature deaths in Pakistan. These correspond to an economic loss of over $3 Billion annually. These costs are borne by individuals, government and other insurance companies and are consisted of tangible and intangible costs. Tangible costs include loss of market productivity, loss of household productivity, property damage, and workplace costs. Intangible costs include suffering and pain and loss of life.

Road safety issue arise because most of the roads were built and designed years ago, traffic volumes have been changed, flaws in road geometric designs, lack of information to drivers, inadequate passing opportunities and lake of provision of other road safety measures. These safety issues can be overcome due to improvement and other transportation interventions.

There are many factors which affect the road traffic safety. These include road engineering factors, environmental factors, driver characteristics, vehicle characteristics, level of traffic rules enforcements and policies regarding the road traffic operations (Sinha & Labi, 2011).

2.2.3. Environmental Impacts Analysis

Environmental pollution is becoming a global hazard and almost every part of the globe is being affected by this. A pollutant is a gaseous, solid or liquid particle which causes adverse impacts on plants, animals, climate and other properties, if it is dispersed and exposed directly to environment. This pollution to environment is increasing with each passing day. And hence it has created an alarming situation for everyone who is involved in any decision making.

Transportation is a mobile source of air and noise pollution which has project and network level as well as global impacts. The transportation sector is a major user and burns the most of world's petroleum. Transportation vehicles emit carbon mono oxides, oxides of Sulfur and Nitrogen, organic compounds and other toxic chemicals that not only affect human health but also have adverse and negative impacts on climate, fauna, flora, rivers and lakes. Based on a study conducted by US Environmental protection agency on a data of last 10 years, the transportation sector contributed about 84% Carbon monoxide CO, 52% of oxides of Nitrogen NOx, and 45% of volatile organic compounds VOC emissions in the country (USEPA, 1992). Emission rates of tailpipe have been reduced significantly over the past few decades. But still actual reductions may be somewhat smaller, since the standard test doesn’t reflect the real conditions of driving and the harmful emissions from the vehicles do not measured directly by these tests (Hombarger et al., 2001).

Transportation vehicles are major source of creating air pollution. Different transportation vehicles produce different environmentally hazardous emissions. Below table 2.11 shows different type of air pollutants emitted from transportation vehicles/sources.

Table 2.11: Air Pollutants from Mobile Transportation Sources (USEPA, 1992)

Pollutant	Description	Source	Effects	Scale
Carbon monoxide (CO)	Colorless and odorless toxic gas formed by incomplete combustion of fossil fuels. The most plentiful of mobile-source air pollutants.	Vehicle and aircraft engines	Human health (undermines oxygen-carrying ability of blood).	Very local
Nitrogen oxides (NO_x)	Primarily, NO and NO_2, caused by oxidation of atmospheric nitrogen. Some are toxic, all contribute to ozone formation.	Engine	Helps formation of corrosive acids that damage materials; kills plant foliage, impairs respiratory system; absorbs light and reduces visibility; contributes to ozone formation.	Regional
Volatile organic compounds	Includes hydrocarbons (HC) such as methane (CH_4). Emitted from unburned fuel from fuel tanks and vehicle exhausts. Smog is a haze of photochemical oxidants caused by the action of solar ultraviolet radiation on HC and NO_x.	Fuel production and engines	Human health, ozone precursor.	Regional
Sulfur oxides (SO_x)	Formed by burning of sulfur-containing fossil fuels and oxidation of sulfur; SO_2 is a colorless water-soluble pungent and irritating gas.	Diesel engines	Human health risks, causes acid rain that harms plants and property; lung irritant; causes acid rain.	Regional
Carbon dioxide (CO_2)	By-product of combustion.	Fuel production and engines	Climate change.	Global
Road dust	Dust particles created by vehicle movement.	Vehicle use	Human health, aesthetics.	Local

There are many factors which affect the emission of pollutants from transportation vehicles. Sinha & Labi (2011) discussed such affecting factors which include roadway characteristics, vehicle characteristics, vehicle speed level and speed variation, type of fuel used and environmental characteristics like humidity level, temperature and altitude etc. Faiz et al., (1996) reported that pollutant emissions from transportation vehicles have effects on vehicle type and speed of the vehicle. Heavy vehicles produce more emissions as compared to lighter vehicles. And as the speed of vehicle increases, the rate of pollutants emission from the vehicle decreases (Faiz et al., 1996). This has been shown in the below figure 2.7.

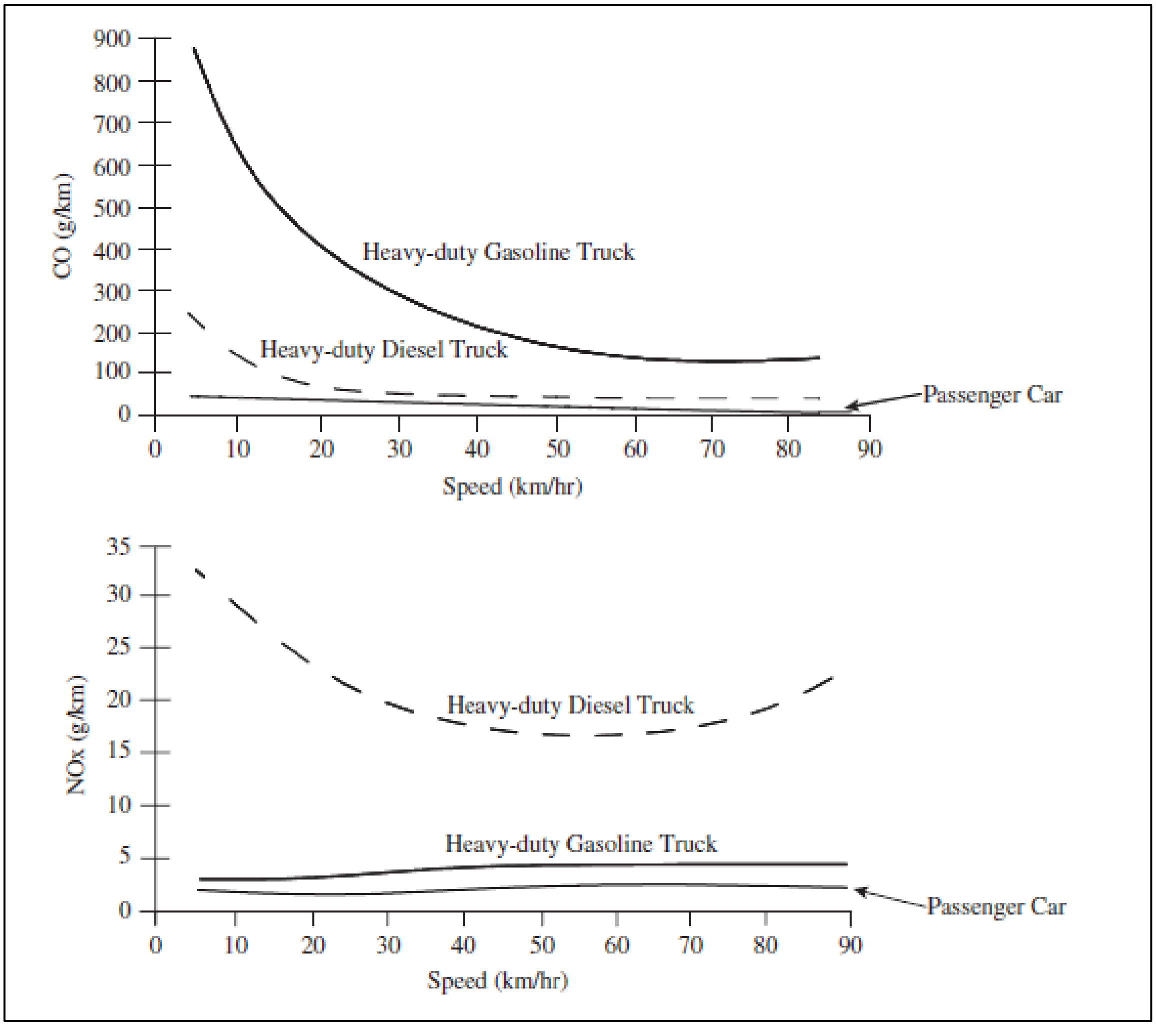

Figure 2.7: CO & NOx emission rates variations by vehicle type, fuel type & Speed (Faiz et al., 1996)

Sinha & Labi, (2011) calculated the emissions from the transportation vehicles and has been given as below:

$$\text{Total Vehicle Emission} = \text{Emissions per vehicle mile of travel} * \text{Total vehicle miles travelled}$$

2.3. SYNTHESIS OF THE PAST RESEARCH

This part of the thesis report presents the short summary of different works executed in different times throughout the world.

2.3.1. General

Internationally different agencies and different countries have carried out studies to evaluate their system of BRT's. But at Pakistan level, there has been no such research carried out. The reason may be that the BRTS is a new concept in the country. So there is a great need to put efforts in this field. Summary of some of the studies regarding the monitoring and evaluation of public transportation systems carried out worldwide are as follows:

Cham et al., (2006) worked on project planning, execution and in the end evaluation of Honolulu BRT. In their study they investigated a broader range of key elements of Honolulu BRT. They investigated several key performance parameters, which include reduced travel time, increased reliability, improved safety and security, providing image and identity, and increased capacity. The study concluded with the assessment and evaluation of transportation system outcomes and benefits (increasing ridership, improving capital cost effectiveness, and operating efficiency), and community benefits (environmental quality and transit supportive development). The authors also investigated different physical and operations related elements of the system such as BRTS pathways, stations, ticketing and fare collection system, vehicles, intelligent transportation system (ITS) and overall system efficiency.

Cain et al., (2009) carried out a study to quantify and analyze the importance of perception and image of Bus Rapid transit System by comparing the BRTS with other different type of public transportation services. The study was carried out in Los Angeles because the city has many public transportation services, which include Lite-BRT, Full service-BRTS, Heavy rail transit and Light rail transit systems. A survey was conducted from different transit users and non-transit users in different areas of Los Angeles. The results of statistically significant differences were categorized in four public transit alternative groups, including local bus transit, light rail transit, Metro orange line and heavy rail transit. The results of these alternatives were compared against their costs and BRT was proved to be the most cost effective one among the other alternatives. The authors also concluded that rating of intangible attributes put a massive impact on perception of the people in terms of issues of urban context. Furthermore, it was extracted that BRTS being the most economical competing option of public transit services in terms of capital cost investment, but still competes well with other rail based modes of public transportation services.

Flynn et al., (2011) conducted an evaluation of Los Angeles metro orange line BRT service. The evaluation report comprised of a brief overview of the project which include historical background, a profile showing different elements of project, cost of the project, planning and design, project implementation and operational tools and techniques etc. further, in the evaluation process, the authors developed different performance parameters to assess and examine the overall BRT system. These parameters included travel time, reliability, capacity, safety and security. Data based on surveys about user perception and satisfaction, project image and identity were also analyzed. The evaluation concluded with an overall consideration of project benefits such as ridership assessment, environmental quality, financial aptness, and overall project performance in meeting the objectives.

Teunissen (2014) in his research work for the evaluation of BRT and MRT in developing countries especially the case of BRT and MRT in Mexico city, argued that mass transit services especially BRT and MRT provide equality, reduced congestion of roads, increased livability, increased livability and productivity and safe journey to the people. In developing countries these benefits get further increased. The author developed an evaluation framework to examine the effects of BRT and MRT in developing countries. Evaluation framework consisted of three main indicators; social, environmental and economic. The social indicators were further divided into safety and equity. The environmental indicators were comprised of three categories; air pollution, climate change and modal shift. Similarly, the economic indicators were classified into construction cost, travel time saving, revenues and operation and maintenance costs. Among these, only the economic indicators were monetized. To assess the individual indicators, the flag model was applied to standardize the impacts. The results of this evaluation process showed that the BRT's performance is better on the basis of operation and maintenance costs, construction cost and modal shift. Whereas the social impacts which include travel time saving, revenue generation, safety and equity etc. of MRT are significant. He further suggested that this analysis is not just sufficient to make an overall decision regarding the aptness of BRT or MRT, but this needs political decision making, keeping in view the results of this analysis. According to Teunissen (2014), this ex-post evaluation framework would help in decision making by further extending and analyzing other indicator of the system.

In a post implementation evaluation of Trans Milenio Bus Rapid Transit System of Bogota city, Hidalgo et al., (2013) investigated the impacts of BRT service and its feeder routes. A cost-benefit analysis (CBA) was carried out where different project performance measures were analyzed and then were monetized for the CBA. These performance measures included as travel time savings, road safety and air quality analysis. The evaluation process also encompassed the analysis of impact of BRT on land use and land values, crime rate, employment, tax collection and overall system efficiency. Besides these positive impacts, the BRT project could not meet the user perception and satisfaction and authors recommended that the BRT system needs some improvement work to overcome the perception of commuters who are the ultimate beneficiaries. Further, the authors recommended that this evaluation procedure can also be helpful in making decisions and evaluating other such public transit services.

2.3.2. Transportation Impacts

According to Sahoo et al., (1996), who worked on the analysis of operational characteristics of traffic condition on two of the national highways of India, observed that as the number of vehicles increase, the traffic flow conditions of the road gets worsen. This implies in terms of reduces travel speeds, increased congestion and a drop in level of service (LOS) and capacity of the highways.

Maitra et al., (1999) modeled the congestion level on urban streets and roads and assessed the level of service on these roads. For this, an integrated methodology was adopted for the congestion analysis so that the reasons of congestion be identified and a proper congestion mitigation measure may be incorporated accordingly. This analysis included the traffic volumes and different operational characteristics of the traffic stream. Based on the level of congestion, ten levels of service were proposed with one in unstable operation zone while nine in the stable zone of flow. Congestion models were developed to assess the impact of addition of an extra lane in the roadway alignment. The model reflected the effect of traffic, roadway and other control conditions and found effective in analyzing and proposing suitable measures to mitigate the congestion on roads. This quantified level of congestion was used to analyze the level of service as an enhanced measure of effectiveness. The boundaries of level of service were redefined and with nine level of service (ranging from LOS-A to LOS-I) in the stable zone of operational flow and other one level of service (LOS-J) in the unstable flow zone. These ten levels of service are more rational representation of traffic condition and can reflect a better understanding and flow quality. The authors inferred that quantified level of congestion has been found as a better assessment tool for the efficacy and estimation of benefits from any transportation intervention.

In a case study of Mexico City's Metrobus, R. King (2014) investigated the metrobus service and concluded that the highest benefit gained by this service was the reduction in travel times of the users since the metrobus uses exclusive lanes and a high frequency of buses which operate at relatively higher speeds. After the benefits gained by saving of travel time, the savings in the cost of operation of public transport come at second number. The authors further concluded that the higher proportion of BRT users were from lower and middle class with a monthly income range of MXN $ 4500-7500. This represents the 2nd quintile of the distribution of the income.

Travel time and traffic impacts of BRTS were analyzed by Patankar et al., (2007). The authors carried out a study to assess the impacts of BRT system on different indicators of traffic quality such as traffic flow, traffic speed, travel time of the passengers, travel delay time, stop time at stations and analysis of fuel consumption. These indicators were modeled to compare the impacts of BRT system with the current mixed traffic. For the analysis of mixed traffic and BRT system, a micro-simulation traffic model was prepared. This model was validated with field data through different statistical tools and procedures. The results of model revealed that the bus based exclusive lane public transportation service has significant impacts on the city traffic for the development of a sustainable public transportation system. The authors recommended that the results of this model can be used to develop a sustained public transportation system in current traffic conditions of India.

Deng & Nelson (2012) worked on southern axis of BRT line 1 of Beijing city. The authors conducted a survey from the passengers of BRT service to know and assess their perception regarding the BRT service. It was to study that what is the attitude and perception of general public regarding the quality and operation of bus based transit system. The questionnaire survey was carried out from 525 BRTS commuters and the data from this survey was analyzed using various statistical methods. The results of the analyzed data indicated that the BRTS has got a good response from the people using it and is a popular service among them. Further, due to the implementation of BRT service, the value of adjacent property has also increased which is a positive indication of this new system. The results further showed that majority of the commuters who use BRTS are work related commuters who use this service more than once daily. The authors argued that the BRTS users have a higher level of satisfaction in terms of system reliability, safety, cleanliness, convenience and comfort. BRT service has also proved to be a cost effective public transit setup and gained a higher popularity among its users.

H. Levinson et al., (2003) worked on different case studies of bus based public transit systems in US. It was concluded by their study that BRT system has helped in reducing the travel time, enhancing the transit related development, attraction of new commuters and improving the safety. BRTS is an economical option of public transit and has flexibility as compared to other public transit alternatives. This service is also capable of meeting the peak hour demand of the riders. The authors suggested that the design of buses and stations need some improvements and the average speed of buses need to be increased. In addition, provision of parking facilities may also be provided along the stations to attract more travelers and enhance system reliability and applicability.

S. Jaiswal et al., (2010) estimated the dwell time at BRT stations and the impact of platform walking in an Australian city BRT project. Conventional dwell time models were used for this analysis and the results presented showed that the walking time to the BRTS station is 10 minutes higher than that it takes to a bus stop. This higher walking time to BRTS bus door leads to a higher dwell time. The authors also heighted the flaws in the conventional dwell time models used for the dwell time analysis of operations of Bus based transit systems.

Krygsman et al., (2004) in their study to analyze the travel time component of multimodal public transportation system, claimed that the successfulness of a public transit system depends a lot on the availability and convenience of its egress and access times. Improvements done for the egress and access of the system can considerably reduce the travel time of the commuters. Egress and access of public transport system were investigated in relation with the overall travel time. The authors concluded that the egress and access times are the function of transportation mode and the direction of trap rather than that of socio-demographic characteristics. Additionally, it was argued that as the trip time increases the egress and access times also get increased.

Jang (2010) studied and analyzed the effect of automatic fare collection methods by using transit smart cards. The author argued that the automatic fare collection methods have brought efficiency and convenience as compared to manual fare collection techniques. The author referenced the introduction of automatic fare collection techniques and transit smart card in Seoul, South Korea in 2004. This new method of fare collection was then upgraded to overall integration of different elements and components of transit system which encompass all the data including, boarding and alighting times of trip, location data, tickets and cost data etc. using this data, the author, examined the possibilities to which this data can be useful for application in transportation planning. Travel data of more than 100 million trips were analyzed to calculate travel times along the stations and the transfer data was obtained. The author inferred that this transfer data may be used for transportation planning purpose. Furthermore, this transfer data may be used to identify the critical locations where the transfer occurs which seek improvement works.

H. S. Levinson, (1983) analyzed the travel time performance of public transit services of different US cities and summarized the results of a survey conducted on different performance parameters such as transit delays, speed and dwell time. These parameters were used as input to plan the changes in transit services and assess their impacts. According to the results extracted from the analysis, the private cars have a speed of 1.4 - 1.6 times higher than that of transit buses. A transit bus takes 11.5 minutes/mile in the CBD, 6.0 minutes/mile in the city and 4.2 minutes/mile in the suburbs of the city. The authors calculated the dwell time of the transit buses as 2.5 seconds + 2.75 times the number of commuters. During the peak-hours of the day, transit buses stop at the 68% - 78% of the designated bus stations. Transit bus speed and travel time were modeled as a function of stop duration at station, station frequency and the stop and go (acceleration and deceleration) time observed. The authors inferred that reducing the dwell time from 20 -15 seconds and the frequency of transit bus stops from 8 – 6 per mile would be reducing the transit travel time from 6.0 to 4.3 minutes per mile. A considerable saving in travel time may be achieved by the reducing the traffic congestion along the public transit routes. By minimizing the stops of transit buses would also improve the performance of public transit system. Other measures to reduce the transit travel time would be to improve the door configuration of the buses, efficient fare collection techniques and easy access to bus stops.

Levy et al., (2010) discussed that traffic congestion has got a serious concern in US as well as throughout the world due to increased urban development and motorization. It was also claimed that previously a good number of work has been done to assess the economic impacts of traffic congestion but a very little work has been done to assess and quantify the effects of traffic congestion on public health. Traffic congestion has varied economic and social impacts on public health and it is a function of urban development, population density, roadway infrastructure and general atmospheric condition. In their study, the authors evaluated the impact of fine particulate matter ($PM_{2.5}$) on public health associated with traffic congestion. 83 urban areas which use the traffic demand models to predict the congestion level were evaluated. Traffic speed and volume data were linked with MOBILE-6 model to estimate the $PM_{2.5}$ emissions. Statistical approaches were used to monetize these impacts. The results showed that monetary value of $PM_{2.5}$ based mortality attributable to traffic congestion was around $ 31 billion as compared to the value of time wastage of fuel of $ 60 billion. This economic impact will grow in future years whereas; the public health impacts will decrease to $ 13 billion in 2020. From these results it was concluded that traffic congestion effects on public health are noticeably enough in magnitude which is to be considered in future assessments to mitigate traffic congestion.

To find out different strategies to mitigate the traffic congestion on urban street and roads and freeways, Daganzo et al., (2002) worked on the said topic and came out with ten strategies that can be helpful in mitigating the traffic congestion. Their effort was backed up with different hardware and software techniques of traffic flow analysis. In all these ten strategies, benefits can be gained accurately from the field data without any modeling procedure. The ultimate goal of the study was to minimize the travel delays for all the users. For ease of analysis and explanation, these congestion mitigation strategies were categorized into four main groups which were further divided to a total of ten strategies. These strategies include Dynamic assignment of lanes, dynamic high occupancy vehicle designations, on-ramp destination specific metering, dynamic management at off-ramp, Dynamic control of merges, management of gridlock, dynamic speed-limits, rationing of free access, diversion actions and dynamic shoulder lane usage. All these strategies can be thoroughly tested; their performance measures can be unfailingly obtained and do not require high-scale models.

Gunn & Sillaparcharn (2007) worked on the valuation of travel time saving and came up with conclusions that the travel time is an important factor considered while choosing any route or mode of transportation. Time is an element that can never be transferred, owned, traded or bought. Authors further inferred that the time saved during having a patronage or a journey can be used in some other productive and useful activity which may have a monetary value as well. Same is the case when time is lost by utilizing it as excessive time in travelling, may be caused by congestion or any other roadway condition. The lost time would have been utilized to have a productive output.

Hamer (2010) discussed the usefulness of parking at public transportation facilities. A safe, accessible, economical and sufficient parking service will attract the private vehicle users to shift towards public transit services for the accomplishment of their journey. The author referenced the Australian government for the implementation and expenditure of money to improve the park and ride services at different railway stations. To check the level to which the persons shift from only-car mode to public transit which the park and ride services help to generate, an interview survey was carried out at designated railway stations. The results of this study revealed that the patronage level to public transit has increased as a result of introduction of car parking facilities at railway stations

M. L. Anderson (2014) analyzed the effect of public transit service on the traffic congestion in US. He claimed that the public transport provides only 1% of total miles travelled in US states but still gets a strong and positive support and response from the public. The author used simple choice mode model and predicted that public transit users are the commuters who travel on the roadways which experience more delays. These have very little impact on traffic congestion. This prediction was tested on the data of a time period when transit workers had a sudden strike in the Los Angeles. Estimation through a regression model revealed that the average delays on the highways increased about 47 % when there were no transit service on the highways and the transit services were ceased. This impact was consistent with the predictions of model and was quite larger than the previous estimates which were just calculated that transit services have a very small effect on congestion mitigation. This analysis revealed that the overall benefits of public transit services are much higher than that of previously believed. The author further claimed that the transit system has found to be traffic congestion relief strategy and improvements in this service would greatly help in smoother traffic operations in the urban roads.

Nurdden et al., (2007) claimed that car is the second highest mode of transportation in Malaysia which contributes around 40% of the movement of people and it is increasing gradually. This is because of poor public transportation facilities being provided. This increase comes up with increased air and noise pollution, increased congestion on roads, alarming road safety conditions and increasing demand for parking space in the cities. The authors studied to implement such policies which come up with reducing the number of private vehicles, discouraging the increased car ownership trends and encourage the use of public transportation services. For this reason, a passenger survey was conducted from the public as well as private vehicle users. The authors developed a binary logit model for three different alternating transportation modes, which include train, bus and private car. Gender, age, economy, travel time, travel cost, vehicle ownership and socio-economic characteristics were found significant factors which affect the person's choice to adopt a certain mode of transportation. Subsidized fares, reduced travel times and shorter distances to public transportation services were the variables that encourage the people to use the public transportation system. Study further concluded that the government should take serious steps and provide better facilities and incentives to get the attraction of general public toward the use of public transportation services.

Fouquet (2012) carried out study on transportation demand and analyzed the trend in price elasticities and income since the period from 1850 – 2010. The author inferred that the income and price elasticities of passenger transportation demand were very large (-1.5 and 3.1 respectively) in United Kingdom in mid nineteenth century. But after that these values have declined. The values of income and price elasticities were estimated to be -0.6 and 0.8 respectively in the year 2010. The trend observed indicates that the future elasticity values of passenger transportation demand may decline further in developed countries. As the economy develops, the elasticity values of passenger transportation demand decrease which is an indication for developing countries.

Litman (2013b) defined transportation demand as the type and extent of travel that commuters choose to perform under specific conditions. The author investigated the influence of different factors such as service quality and trip price on travel demand. It was also determined that how the effect of these factors can be measured using the values of elasticity and how these values can be used to predict and analyze the impacts of changes in price and service attributes. Different factors were analyzed and it was concluded that there are certain factors which influence the travel demand, these factors include demographic (population, age, income etc.), commercial (job, business activity etc.), traffic (mode, route, services etc.), demand management (parking management, user information, promotions etc.), land use (Density, proximity, connectivity etc.) and prices (transit fare, fuel rates, parking fee, tools and taxes etc.). Main findings of the study included as higher value travel has lesser sensitivity to change in trip price, higher income groups are less sensitive to increase in price but service quality and opposite is for the lower income families, travel prices tend to effect the household budgets of the lower income families, impacts of changes in price increase over the time, travelers are more sensitive to price changes which they consider to be durable, as the travel options increase, the changes in the trip price becomes more sensitive and fare collection and its structure has also effect on travel demand. Changes in the trip price may affect trip frequency trip mode, trip route, trip destination, parking services, and service type selected. scheduling, Furthermore the results revealed that when there are different modes, routes, vehicle types, parking services and travel time variations in competition, the elasticity responses have a different pattern. For example, changing the service quality and trip price of one mode influences the demand of other modes in competition. This was termed as cross elasticity. According to the author, there has been observes an increasing trend in transportation demand management. This reflects in terms of pricing reforms, congestion management, accident preventions, environmentally compatible and traffic management strategies. Countries that develop consumer-based tested and efficient trip prices result in transportation demands that provide more efficient and reliable transportation system with lesser associated problems and complications. It was recommended that improved and calibrated transportation demand models are essential tools to help the planners and policy makers in examining the transportation and traffic related problems and present suitable and reasonable solutions to them. The developing countries may find it suitable and essential for them to establish capacity building programs and data collection procedures to support and upkeep model development.

Redman et al., (2013) studied that what qualities of public transport attract the private vehicle users. It was tried to explore the attributes of public transport and thus to present appropriate measures to bring improvement in the system. In this study, the authors used a qualitative methodical review and concluded that the frequency and service quality are the most important and significant attributes that attract the private vehicle (car) users toward public transport. Other attributes included as reduced fare level and individual perception may also help in encouraging the people to shift from passenger cars to public transport services. Mobility, accessibility and perception by target market can also help to attain a sustained public transportation system.

Chiu Chuen et al., (2014) worked to analyze the modal share of private and public transport in Klang valley of Malaysia. It was found that 17% of the people use public transport while 83% of the people use their private vehicles in order to complete their daily transportation needs. This is because of ineffective, poor and inefficient public transportation facilities. The government had the aim to bring the share of public transport to 50% by 2020. Different strategies for this purpose were sought and mass transit system was found suitable and finally was proposed. It was to cover 141 km integrated with current rail network of the valley. The authors evaluated the modal shift being done by the implementation of mass transit system. A questionnaire survey was carried out from different households to check the perception of people towards the new public transportation system. This was found helpful for the decision makers to know that what attributes of public transport will help to make the mass transit system effective. The results of the survey indicated that people would shift and prefer to shift towards public transport, if the proposed mass transit system provides accessibility, reduced travel time and costs. Furthermore, the people may also be induced to shift towards public transport if government introduces parking costs, increased car and fuel prices. Same policies may also be helpful for shifting people towards bus based public transportation system.

2.3.3. Safety Impacts

According to Litman (2013a) public transportation is a safer mean of movement of people as compared to the automobile travel. The safety is in terms of lower crash rates. Public transport has the casualty rate of about tenth the traffic crashes as compared to automobile transport. The people residing in the transit-oriented neighborhood have a lower per capita casualty rate comparing to automobile-oriented neighborhoods. The author further claimed that public transit has a lower crime rate as that of private transport. If the security and surveillance systems of public transport are enhance, it becomes a very secure and reliable mean of transport for the people to overcome their daily transportation needs. At the same time, if security services of public transit are bypassed, then the chances of diverting it become higher. Different factors contribute to increase the safety issue of public transport and hence results in underuse of transit services. These factors include transit related crimes and crashes reported by media, poor safety arrangements and unreliable safety measures within the bus. Author suggested that public transport services can be made effective, if the transit authorities work to improve the safety arrangements in and out of the buses, platforms and stations. Proper surveillance can also improve the ridership of public transportation services.

Delbosc & Currie (2012) claimed that people's perception on safety has a major impact on attracting them to public transport services. The author studied different factors that influence the perception of people regarding the crime risk. In this study, structural equation models were used to find out the impacts on public transit safety perception and the related influence of these perceptions of the transit ridership. For this purpose, a survey was carried out in an Australian city of Melbourne. The survey results showed that the highest influence on public transport was the feeling of safety. This means that how much people find themselves safe on roads, buses and streets at night while using the public transport. The influence on safety was found significant and more that of gender and age. Further, it was shown that the people who use private vehicles for their transportation needs would switch to public transport services if their fear regarding the transit safety issues has been removed and a trust is developed for a safer public transport system. The author concluded that people's confidence and transit safety has a major indicator in determining the ridership of public transport services. Perception of transit safety also dictates the people to choose a certain public transportation service.

2.3.4. Environmental Impacts

Rietveld (2001) analyzed the effects of public transport on environment and emissions produced by the transportation vehicles. Analysis of policies regarding the capacity management was also done on the Netherland railway networks. The results showed that capacity analysis during off-peak period is primarily influenced by the demand levels in the peak periods of traffic flow. The factors which effect the environment include the frequency changes and increase of vehicle size. Marginal costs were incorporated instead of average costs. Further it was concluded that marginal environmental costs during peak period of flow are much higher than that of off- peak periods. Also, the policies regarding the average environmental performance has a major effect.

According to Newnam (2011), public transportation services has many benefits. These include safety, mobility, reduced travel time, reduced congestion and economic benefits. At the same time public transport provides environment friendly services for people and related businesses. This is because of the fact that due to public transportation services, the number of cars and other vehicles gets decreased which ultimately reduces the environmentally hazardous gases and reduced the congestion as well. This proves not only a better air quality but reduced noise and a safer environment. The author quoted a FTA study, where presented that Americans complete ten billion trips every year through public transport. Use of public transport decreases the utilization of fuels and thus helps in conserving the energy and fossil fuels. In the Los Angeles city, there operate around 2500 metro buses, other light and heavy buses, subway trains and other rideshare services. All these prove to be environment friendly options of public transportation services.

2.3.5. Economic Impacts

Kim et al., (2004) developed a framework to analyze the economic impacts of highway projects on the national economy of Korea. The evaluation framework consisted of two models. One of them was to measure the accessibility and shortest route of the highway project while the other model was to assess the effects of the highway project on the national GDP, income distribution and other socio-economic attributes of the population. The model simulation based on these attributes allowed the decision makers to decide that among various highway development projects, which one comes out to be the best option. The models results revealed that all the highway projects came up with positive impacts on the attributes in consideration.

Li & Madanu (2009) emphasized on the project assessment and evaluation in the decision making process regarding any major investment. The authors conducted a case study to analyze the effects of uncertainty and risk on the project benefits and costs estimation. The results of the case study showed that the estimated life cycle benefits and costs have impacts on project selection results.

According to Fuller (2010), life cycle cost analysis (LCCA) is the method to assess and calculate the total cost of ownership of the facility. This analysis considers initial capital costs, all the costs, expenses and savings of the project, maintenance costs and the disposal value. This approach is useful to compare the alternative projects with same requirements in terms of project operations and performance but different costs and savings. Other economic evaluation options include Net Savings approach, Investment to cost ratio method, payback period method and internal rate of return method.

CHAPTER 3

3. METHODOLOGY

3.1. GENERAL

Public transport is a mean by which many people in one time move to different places sharing the same common passenger transit service. These services include wagons, buses, trams, rapid transit buses and rails, ferries etc. Public transport is relatively an economical option for the people to opt. In a developing country like Pakistan, people mainly rely on public transport for their daily transportation needs. That's why Government has initiated different public transit services. So, the Monitoring and Evaluation of such public projects is mandatory to assess the current project and at the same time helps in decision making regarding the implementation of such projects. Like many other fields, improvement, development and innovation has also been made in the field of public transportation. Among these innovations, Bus Rapid Transit System (BRTS) is an important one. In Pakistan, the Govt. has initiated certain public transport projects to facilitate the general public. BRTS projects have been started in different cities and have also got popularity. BRTS is a new concept in Pakistan, so assessing its viability is as important.

Keeping these points in mind, it has been tried to evaluate the Bus Rapid Transit System (BRTS) of Rawalpindi-Islamabad. The overall framework of the evaluation process is shown in the figure 3.1.

3.2. STUDY AREA DESCRIPTION

Islamabad-Rawalpindi, also called twin cities are commonly viewed as one unit. Islamabad is the capital city of Pakistan with a population of two Millions and the population of twin cities is over 4.5 Million inhabitants. Islamabad is the tenth largest city of Pakistan whereas the Rawalpindi is at the fourth position located in the Islamabad capital territory (ICT). The Islamabad-Rawalpindi metropolitan area is the third largest metropolitan area of the country. The growing rate of this metropolitan area is over 4% per year. After the Islamabad became the capital city in 1961, the

Rawalpindi area got a boost and its politics and socio-economic scenario got changed. Islamabad is a well-planned, maintained and a modern city located in the Pothohar plateau on country's north eastern part. It is a well-organized international city divided into different sectors and zones and is considered as country's most developed city. Islamabad city hosts a number of ambassadors, diplomats, politicians and other govt. employees. These two cities have a unique importance, as Islamabad being the Capital city of Pakistan whereas in Rawalpindi city, there are the Headquarters of the Armed forces of Pakistan.

Both cities are linked through a network of roads with Murree road, Islamabad Highway and Kashmir Highway are the main links and carrying the major traffic load. During the last few years

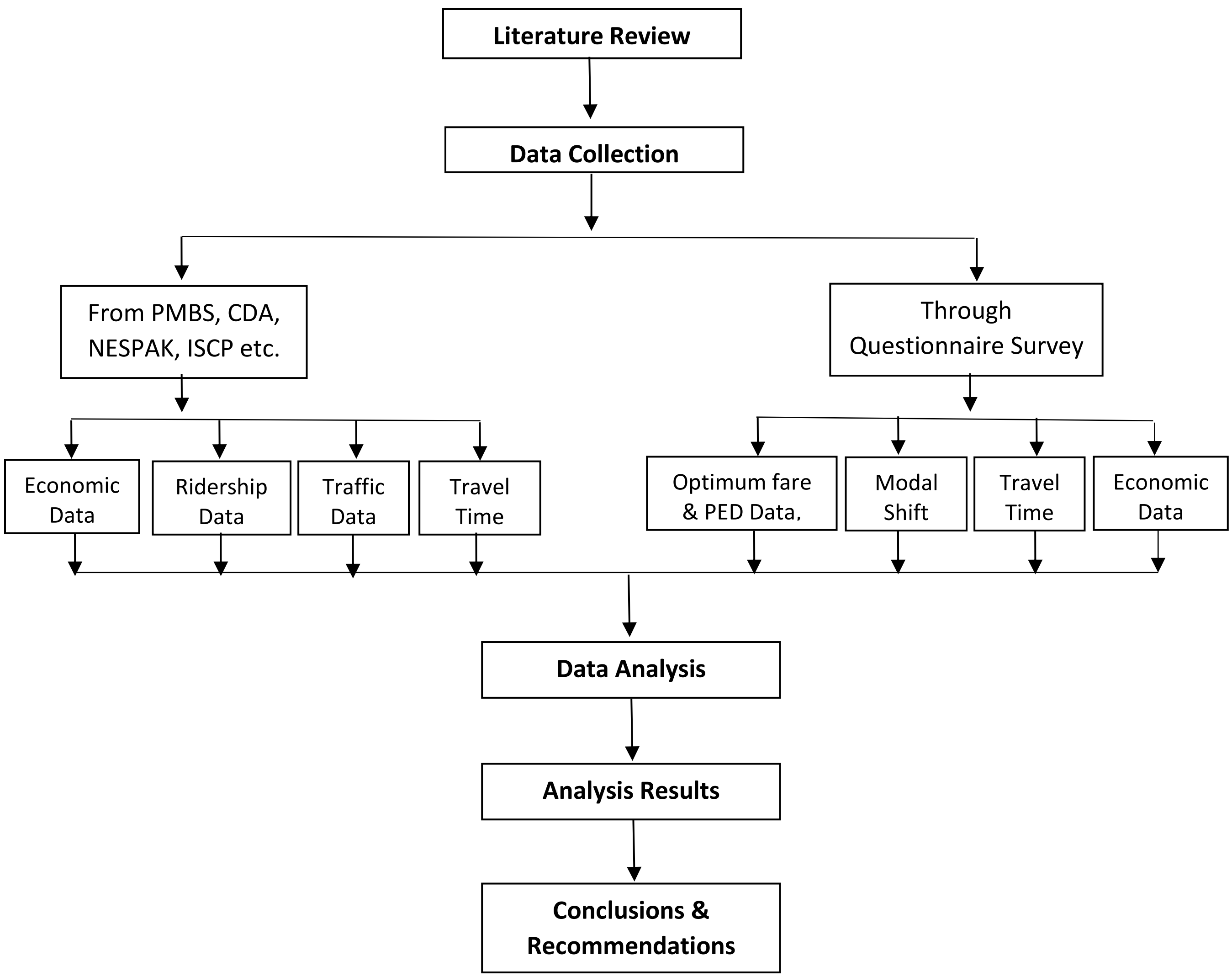

Figure 3.1: Overall Evaluation Framework

there has been a rapid increase in the population, resulting in unprecedented increase in vehicular traffic. This increased motorization stemmed in increased delays, traffic congestion, air and noise pollution, and created socio-economic problems for the people living specially in the Rawalpindi area. Murree road being located in the Rawalpindi area and a major load carrying artery badly experienced these problems. These problems started creating their effects in the federal capital as well. Figure 3.2 shows the Islamabad and Rawalpindi area with major roads and railway tracks displayed on the map.

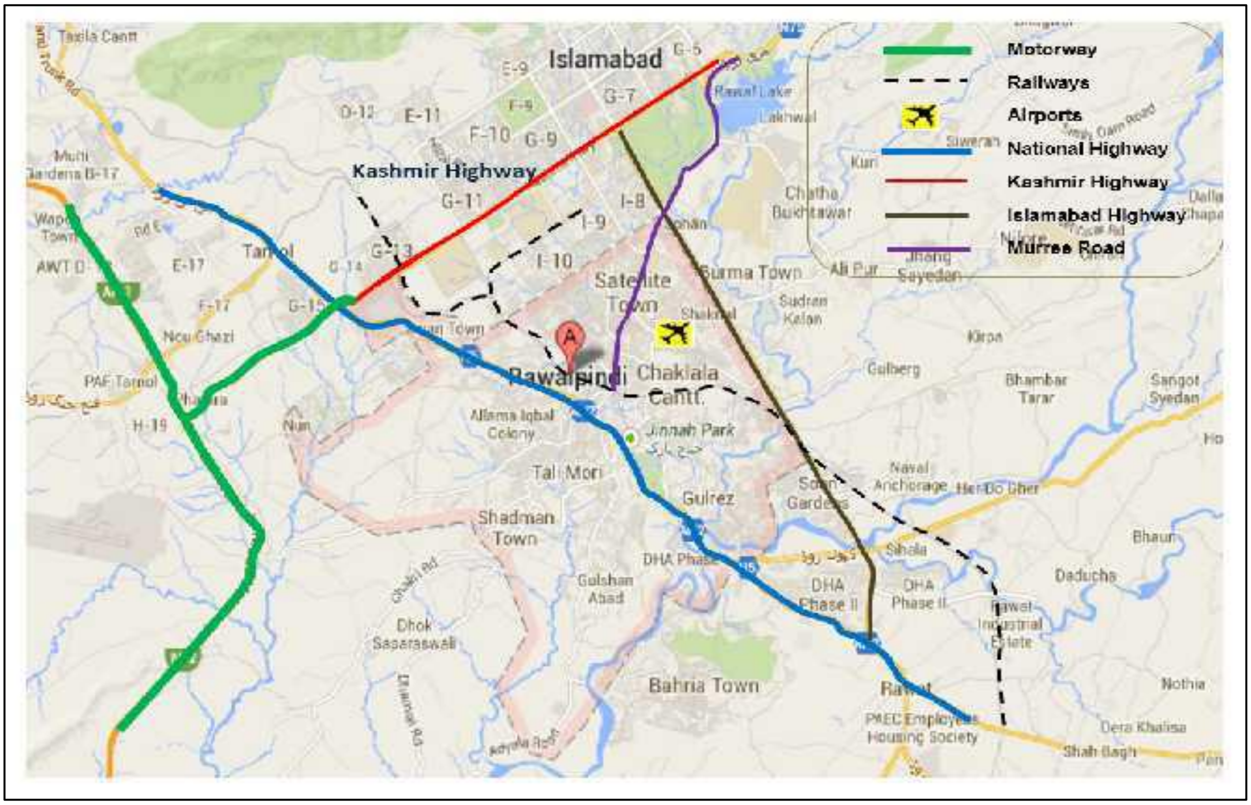

Figure 3.2: Study area (NESPAK, 2015)

For the general public to overcome their transportation needs, they rely on public transport which is a major contributor in the mix of traffic. The condition of public transport service is far beyond any standard. That's why most of the people are dependent on private transport which is also a major contributor. Poor condition of public transport encourages the use of private vehicles which results in congestion, excessive delays, environmental degradation and personal dis-satisfaction. Both the cities had no organized and reliable urban public transport facility. The current public transport comprises of minibuses, wagons, vans, Suzuki carriers and Chingchi's. The level of service provided by these services is far below any acceptable level. Based on an estimate, there are 210,000 vehicles ply on three major arterials which connect the twin cities and carry around 530,000 passengers on daily basis. Current public transport services were very far beyond to even accommodate this demand.

3.3. PROJECT DESCRIPTION

Keeping in view the current public transport condition, the federal and provincial governments joined hands together to overcome these transportation and related issues. In a meeting, the Capital Development Authority (CDA) Islamabad, Rawalpindi Development Authority (RDA) and Punjab Metrobus Authority (PMBA) decided to alleviate these problems The Punjab Metrobus Authority and Capital Development Authority therefore proposed a Mass Transit System (MTS) to provide safe, organized, efficient, reliable and comfortable urban transportation system to the citizens of the twin cities and to cater for the public transport demand in Rawalpindi (within RDA limits) and Islamabad. The proposed MTS will offer high quality of service to the residents, meet the demand for urban transport and contribute towards developing sustainable transport system for both the industrial and national capitals. In order to overcome the transport related problems as described above, it is necessary to provide a MTS with the following features:

- Dedicated routes to facilitate commercial and residential development.
- Optimized public transport network providing coverage to the whole of twin cities through a mix of main and feeder routes.
- Integrated transport network for maximizing ridership.
- High level of service in terms of speed, frequency and easy accessibility to reduce car/motorcycle dependency.
- Safe, secure, economical, comfortable and environmentally sustainable system.
- Operated via Off-board e-ticketing on trunk routes for passenger convenience.
- Reliable and dependable, meeting needs and aspirations of the community.

Different mass transit options were discussed for the betterment of public transport in Islamabad and Rawalpindi areas. Hence, Bus Rapid Transit System (BRTS) was found to be a suitable and applicable MTS option. Such a BRTS project has recently been implemented in Lahore, the capital city of Punjab province, administrated by Punjab Metrobus Authority. Finally it was decided to opt the Bus Rapid Transit System (BRTS) for the twin cities.

National Engineering Services of Pakistan (NESPAK) was given the consultancy services for this BRTS project. NESPAK developed four Mass Transit Corridors in the base model of Year 2014. The modeled ridership of each Line with its priority of construction is as follows:

- **Line 1: Red Line-**Sadar to Pak Secretariat via Murree Road, Faizabad, IJP, 9th Avenue and Jinnah Avenue.
- **Line 2: Orange Line-** Islamabad Morr to Bara Kaho via Kashmir Highway.
- **Line 3: Green Line-**SawanAdda to 9th Avenue via GT Road, PirWadhaiMorr, IJP.
- **Line 4: Blue Line-** Katchery to Faizabad via Airport Road, Koral Chowk and Islamabad Highway.

These have been shown in the figure 3.3.

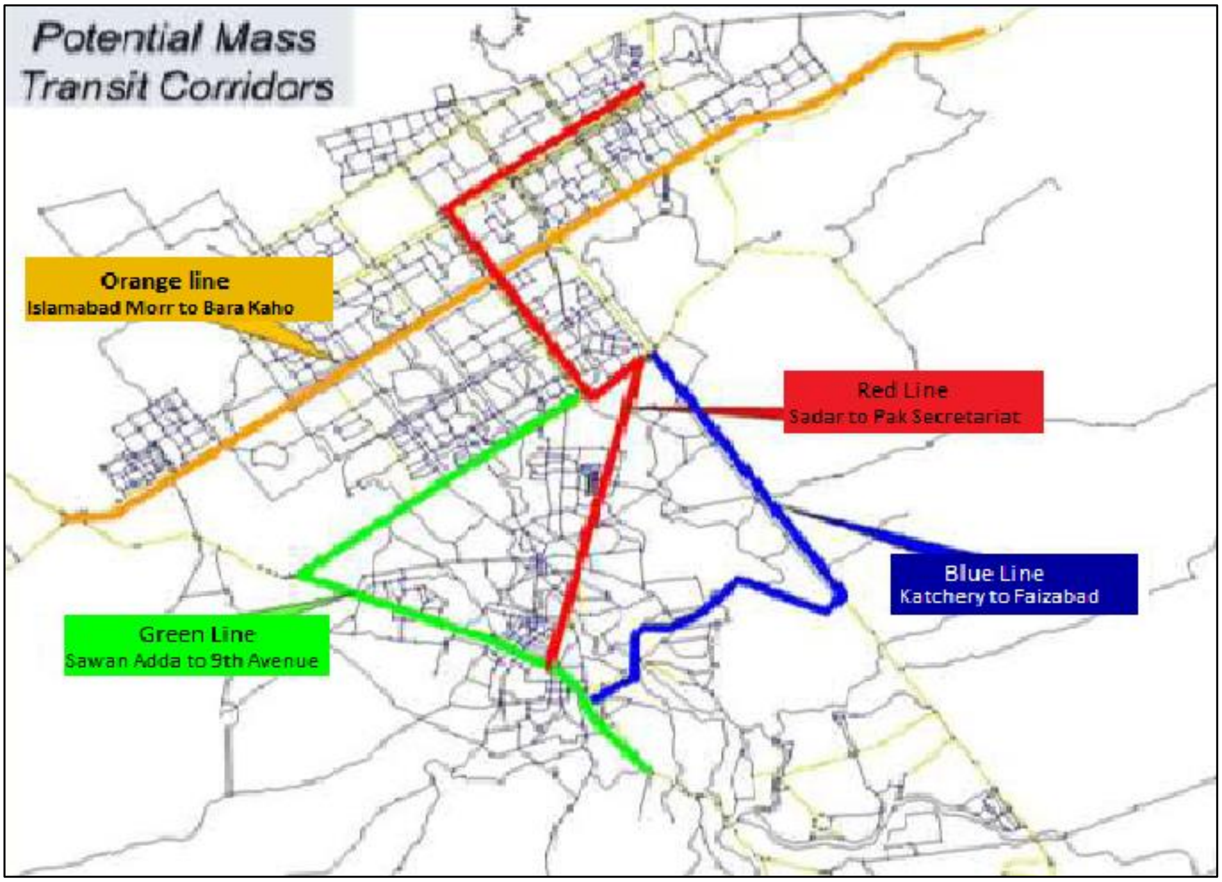

Figure 3.3: BRTS Potential mass transit corridors (NESPAK, 2015)

Table 3.1: BRTS Potential mass transit corridor Details (NESPAK, 2015)

Priority	Line	Year of Construction	Length (KM)	Ridership (Pass/day)* (2014)	Passenger Km per Day
1	Red Line	2014	22.4	217,863	1,592,564
2	Orange Line	2016	19	31,749	995,405
3	Green Line	2018	18	86,565	493,182
4	Blue Line	2020	15.8	71,743	380,894

* Ridership calculations are based on assumption that all four lines are functional.

On 8th September 2014, NESPAK was asked to develop three more Mass Transit Network Options with different scenarios. Eight Rawalpindi and five Islamabad new bus routes were also given for analysis. Mass Transit Network options are as follows provided in the figures 3.4, figures 3.5 and figures 3.6:

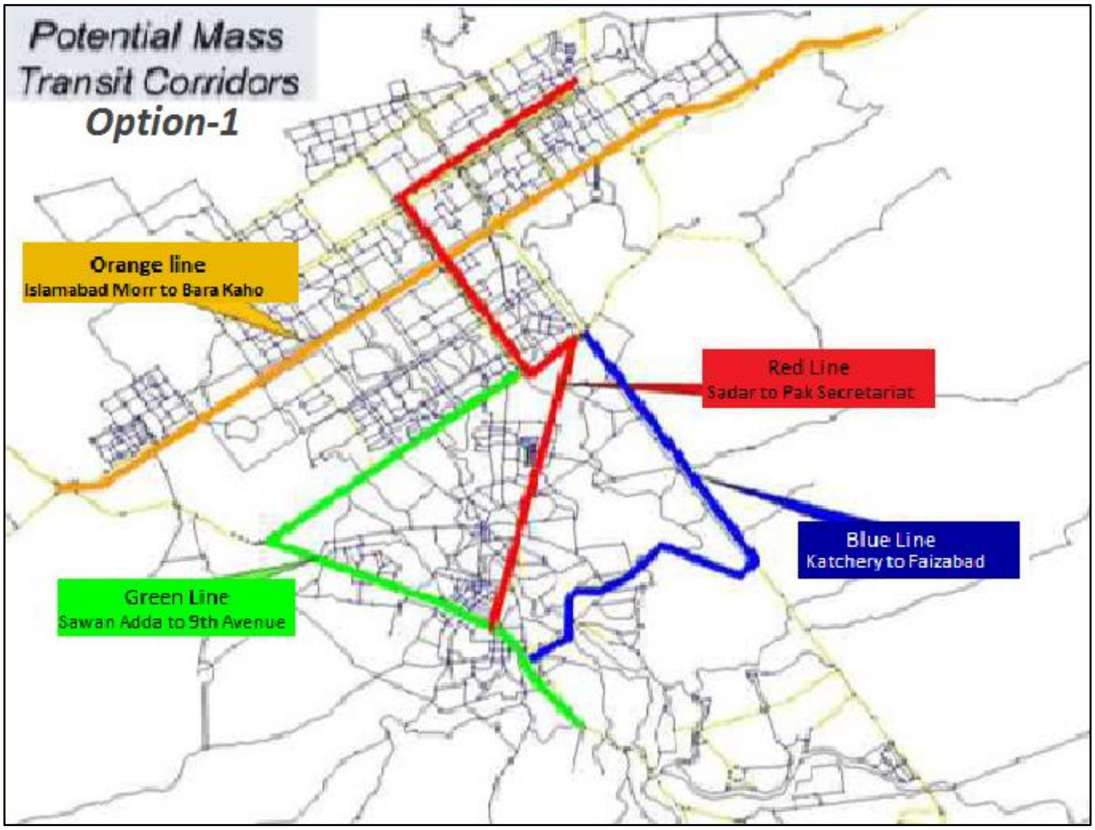

Figure 3.4: Potential mass transit corridors (Option–1) (NESPAK, 2015)

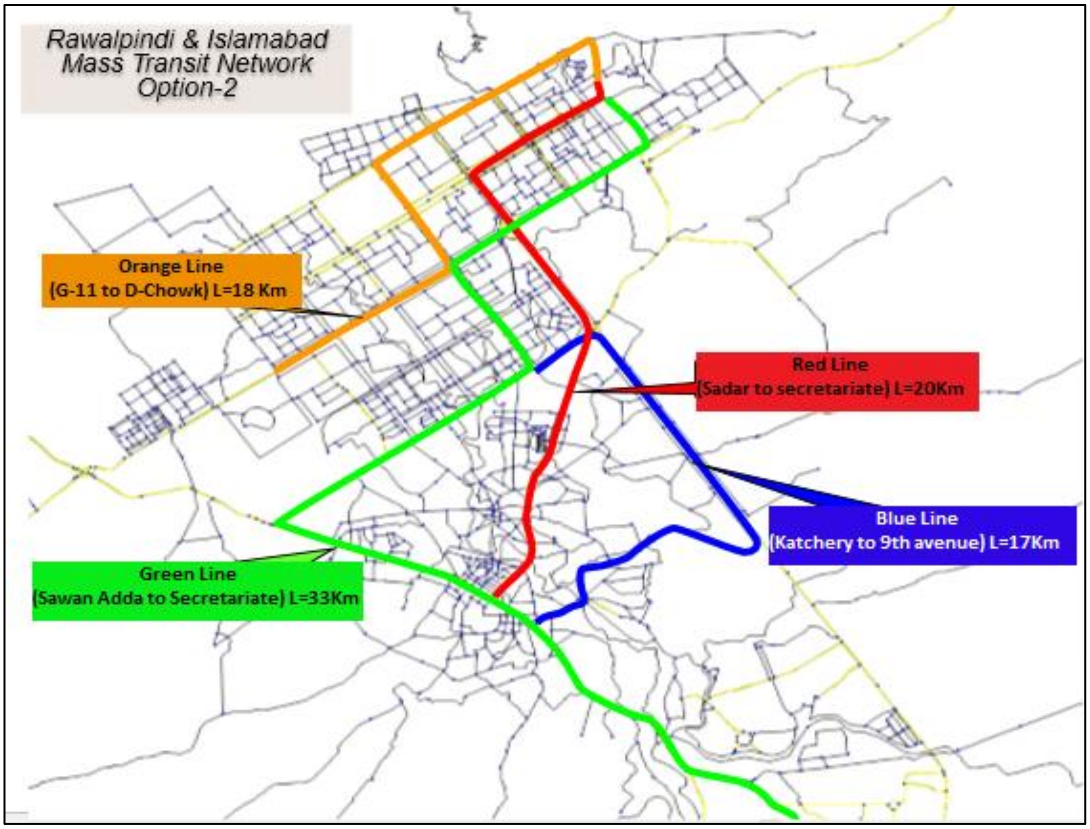

Figure 3.5: Potential mass transit corridors (Option–2) (NESPAK, 2015)

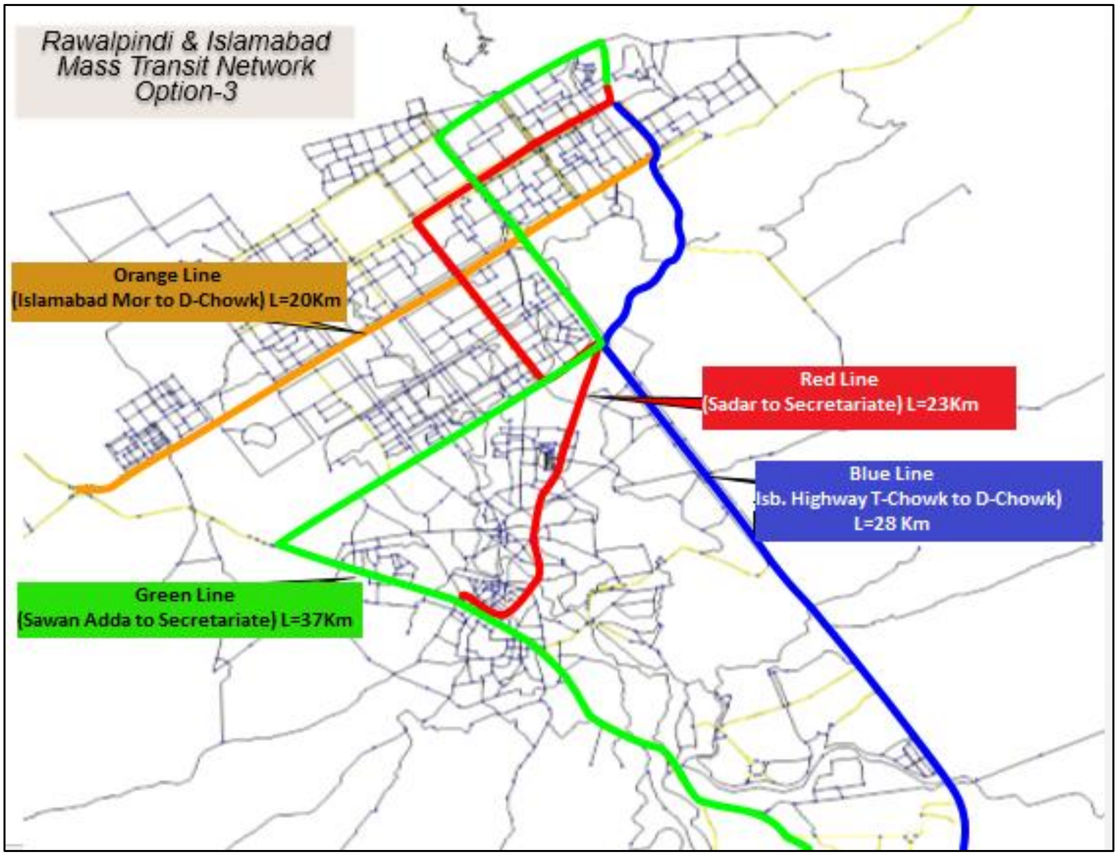

Figure 3.6: Potential mass transit corridors (Option–3) (NESPAK, 2015)

The consulting team of NESPAK developed a model and each Mass Transit Network Option was run in the Model with different scenarios. Efficiency of each Scenario with respect to Passenger mobility and access was determined which is as under:

Table 3.2: Mass Transit Network Options with Different Scenarios (NESPAK, 2015)

Sr. No	Mass Transit Network Options with Different Scenarios	Passenger Mobility
1	Scenario-01_00 (No BRT with PMA PuT routes no existing PuT routes)	74.62%
2	Scenario-02_01 (Option-1 Lines with existing PuT routes)	96.69%
3	Scenario-02_02 (Option-1 Lines with PMA PuT routes & existing PuT routes)	98.26%
4	Scenario-03_01 (Option-2 Lines with PMA PuT routes no existing	74.74%

	PuTroutes)	
5	Scenario-03_02 (Option-3 Lines with PMA PuT routes no existing PuT routes)	72.77%
6	Scenario-04_01 (Option-2 Lines with PMA PuT routes & existing PuT routes)	98.05%
7	Scenario-04_02 (Option-3 Lines with PMA PuT routes & existing PuT routes)	97.38%

Scenario-01_00, Scenario-03_01 and Scenario-03_02 show that about 25% to 30% passengers could not ride or get access to any of Public transport services. Considering the above passenger mobility results Scenario 2 and Scenario 4 were selected for further analysis and ridership calculations. Model was again run for these scenarios and following results were obtained:

Table 3.3: BRTS different option scenarios (NESPAK, 2015)

Scenario-: 04_01 (Option-2 Lines with PMA PuT routes & Existing PuT routes)					
Priority	**Line**	**Length (Km)**	**Ridership (Pass/day) (2014)**	**Passenger Km/Day**	**Pass km / Bus km**
1	PMA-Scenario1-BRT-01-Red Line	20	178,289	1,345,394	70
2	PMA-Scenario1-BRT-02-Green Line	33	169,560	1,164,187	37
3	PMA-Scenario1-BRT-03-Orange Line	18	53,701	184,489	11
4	PMA-Scenario1-BRT-04-Blue Line	17	63,631	333,225	20
Scenario-: 04_02 (Option-3 Lines with PMA PuT routes & Existing PuT routes)					
Priority	**Line**	**Length (KM)**	**Ridership (Pass/day) (2014)**	**Passenger Km/Day**	**Pass km / Bus km**
1	PMA-Scenario2-BRT-01-Red Line	23	195,452	1,440,319	65
2	PMA-Scenario2-BRT-02-Green Line	37	126,876	886,953	25
3	PMA-Scenario2-BRT-03-Orange Line	28	71,731	533,847	20
4	PMA-Scenario2-BRT-04-Blue Line	20	87,993	470,527	25

3.3.1. Priority Line

Based on these results of all the scenarios, Red line ranks on the top and thus is selected as the priority line. The consultants again evaluated priority 1 line in detail with tow following scenarios;

- With feeder routes and fare integration.
- Without feeder routes and fare integration.

Table 3.4: Priority Line Scenarios (NESPAK, 2015)

Priority Line Scenarios	2014-2015
Ridership without feeder routes/fare integration	1,35,005 passengers/day
Ridership with feeder routes/fare integration	2,19,500 passengers/day
Load	6,000 pphpd

* Ridership calculations based on with only Red Line

3.3.2. Future demand Estimation

Ridership demand for future years 2025 and 2035 was calculated as shown in below figure 3.7 and figures 3.8.

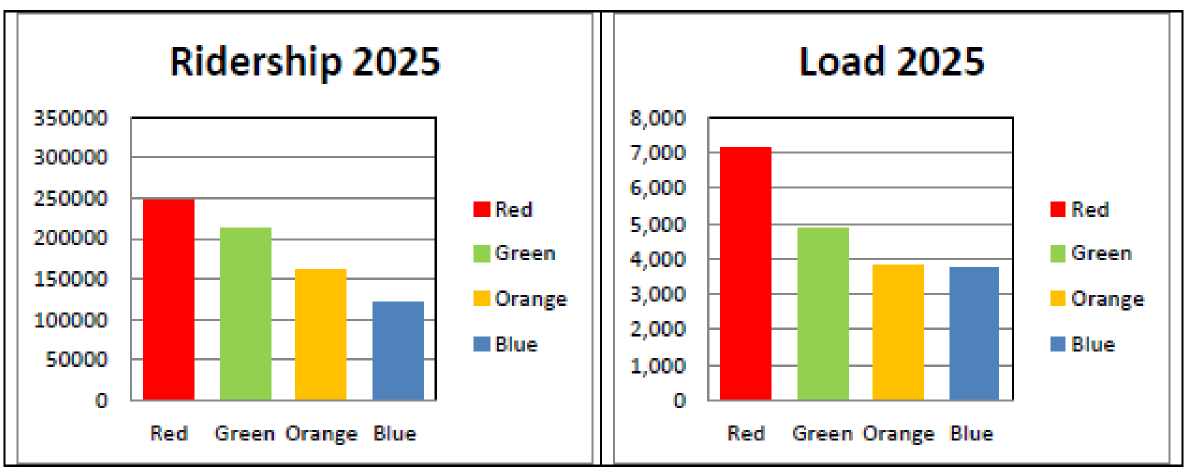

Figure 3.7: Ridership & Load for Year 2025 (NESPAK, 2015)

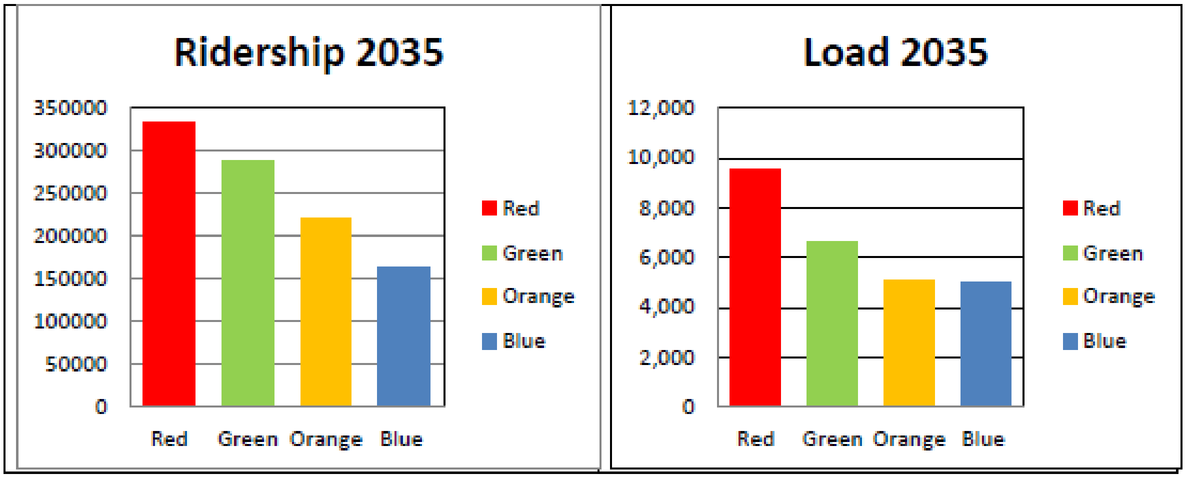

Figure 3.8: Ridership & Load for Year 2035 (NESPAK, 2015)

* Ridership is with only Red Line in functional.

3.3.3. BRTS Rawalpindi-Islamabad General Characteristics

The consultants determined the Corridor Capacity, Bus Speed and Fleet size of the system. The project was analyzed for its economic viability based on benefits to the public transport users and overall congestion relief to road users in mixed traffic. Important Components/Features of this system are briefed as under:

- One Station per Kilometer
- Grade Separated Passenger Access
- Signal Free Dedicated Bus Corridor
- Level Boarding with Closed Stations
- Off-board Fare Collection with Smart Card
- Escalators, elevators and Platform Screen Doors
- Online Driver Information and Vehicle Tracking
- Variable Message Signs for Passengers (VMS)

Some other project specific characteristics of BRTS Rawalpindi-Islamabad are as follows:

Table 3.5: Priority Line Scenarios (NESPAK, 2015)

Sr. No	Red Line Characteristics	Year 2014-15
1	Corridor Length	22.4 Km
2	Corridor Capacity	12,465 pphpd
3	Travel time for a complete cycle	1.6 hours
4	Fleet Size	69 Articulated Buses
5	Average Speed	32 km/hr
6	No. of Bus Bays per Station	3 Nos.
7	Vehicle capacity	160 Pass/Veh
8	Service frequency	43 Veh/hr
9	Construction Cost	Rs. 44.96 Billions
10	EIRR (Economic Internal Rate of Return)	22%

3.4. FORMULATION OF QUESTIONNAIRE FORM

Data is one of the most important element in any research study. All the analysis is done and results are extracted from the data. For data collection, it is important to know that what sort of data is needed and how the required data can be obtained or collected. Data mainly has two types; primary and the secondary data. Data collection procedures have been discussed briefly in the below sections of the chapter. Secondary data can be collected or obtained from different departments and organizations, whereas the primary data is collected directly from the sample of population. This primary data can be collected in the form of interviews, questionnaire surveys, experimental studies and observations etc.

For collection of primary data for the research study, the questionnaire survey method was adopted. This method needs a list of questions to be asked from the BRTS commuters. A well designed questionnaire is necessary for any survey or study. For the design of questionnaire form, it was focused hard to get it a complete and a brief one. It was also tried that the questionnaire form should be simple and easy to understand for the respondents and there should be an ordered flow of questions. For the collection of primary data, two questionnaire forms were formulated and the questionnaire survey from the BRTS commuters were also conducted in two stages.

First questionnaire survey had two main parts, first part included the basic information of the respondent and the second part included the main body of questionnaire. The information gathered from this survey included the travel time data, modal shift data, basic safety and economic data.

After completion and basic analysis of data from the first questionnaire survey, the second questionnaire survey was conducted at BRTS stations from the commuters. The data from this questionnaire survey was extracted for the modal shift analysis, ridership demand analysis, optimum fare calculation and price elasticity of demand (PED) analysis.

3.5. DATA COLLECTION

Data is commonly referred as the basic and building block to any research process. Data collection is the process through which data from different sources is gathered, assembled and organized to make this data useful for any statistical outcome or to extract any conclusions from this data. This is an integral and a critical part of any research process. At the same time, proper collection of data is as important. Properly collected data will lead to true conclusions whereas improperly collected data will lead to the deviation from the true results. The data for this research study of post implementation evaluation of BRTS Rawalpindi-Islamabad was collected from two main sources; i.e. Primary and secondary sources.

3.5.1. Primary Data Collection

Data that is collected and observed directly from the sample of population is called primary data. This is also called first-hand experience data. This data is collected from the population sample in different ways which mainly include focus groups and different type of surveys. The main source of primary data for this research work was the Questionnaire Survey (QS). This questionnaire survey was conducted from BRTS commuters at BRT stations, platforms and in the buses.

Data collected from primary survey were used for travel time analysis, modal shift analysis, optimum fare calculation, ridership demand analysis and price elasticity of demand. For travel time analysis, questions were asked from BRTS commuters about their previous travel time, current travel time, travel time to BRTS station from their origin, travel time from BRTS station to their destination. Then the previous and the current travel times were compared to get the net results of the travel time in terms of travel time saving or increased travel time. Questions for the modal shift analysis included the previous modes of the BRTS users from which they have been switched to their current mode i.e. BRTS. This analysis gave the modal shift in percentage. Questions for willingness to pay (WTP) provided the data for the analysis of optimum fare calculation, ridership demand analysis and price elasticity of demand.

3.5.1.1 Selection of Sample Size

When it is to get information about a large population, it is almost impossible to get information about every entity in that population. Also at the same time it is not feasible and practicable to survey and get information about the whole population. So, to cater this, the sampling procedure is used. Sampling is the procedure to get the replica of original population. This is an important tool in statistics to extract inferences and results from a large number of data or from a population. In this technique, a smaller portion of population is carefully taken so as this smaller portion replicates the whole population. In statistical terms, a population can be defined as the complete set of data and the sample can be said as the sub-set of this population. A good sample is one in which the sampling is random and each entity has the equal chance of being selected.

One of the most critical aspect in conducting a survey from a sample is the determination of sample size for the analysis. A suitable and a decent sample size predicts well the population and a deficient sample size under or over-estimates the real population. That’s why it has always been emphasized to calculate a fair and suitable size for the sample.

To get a fair and a decent survey sample size, literature was studied and sample size calculation method by Dr. Don A Dillman was found to be a suitable one. Dr. Dillman is a professor in

Sociology department at Washington State University. So, Dillman method gives the following formula to calculate the size of the sample.

$$N_s = \frac{(N_p)(p)(1-p)}{(N_p - 1)\left(B/_C\right)^2 + (p)(1-p)}$$

Where,

Ns = completed sample size needed (notation often used is n)

Np = size of population (notation often used is N)

C = Z statistic associate with confidence interval (1.645 = 90% confidence level; 1.960 = 95% confidence level; 2.576 = 99% confidence level)

p = proportion expected to answer a certain way (50% or 0.5 is most conservative)

B = acceptable level of sampling error (0.05 = ±5%; 0.03 = ±3%)

So, the sample size was calculated from the above formula and it came out to be 187 by using the population size as 100,000 because according to Dillman, the population size exceeding 20,000 has a small effect on sample size and it varies very low. Confidence level was taken as 90% and the proportion expected to answer a certain way was selected as 0.5 which is the most conservative approach. Acceptable level of sampling error was taken as 0.06.

Once the sample size was calculated and the questionnaire survey form was developed, then the next step was to select the sites for the conduct of questionnaire survey. The site selection procedure has been discussed below.

3.5.1.2 Selection of Sample Site

One of the important parameters that need to be addressed is the selection of a fair and suitable selection of site for the conduct of questionnaire survey. Since the survey was to be carried out from BRTS users, so the site for conducting the survey consists of BRTS stations. There are total 24 stations and questionnaire survey was conducted from BRTS commuters at these BRT stations, platforms and in the buses. Due to security and managerial issues, it was not allowed to carry out any such survey activity at the stations. So, a proper sanction from the Punjab Metrobus Authority (PMBA) was taken to carry out the questionnaire survey. The following figure 3.9 and figure 3.10 show the survey and the stations location where the survey was carried out.

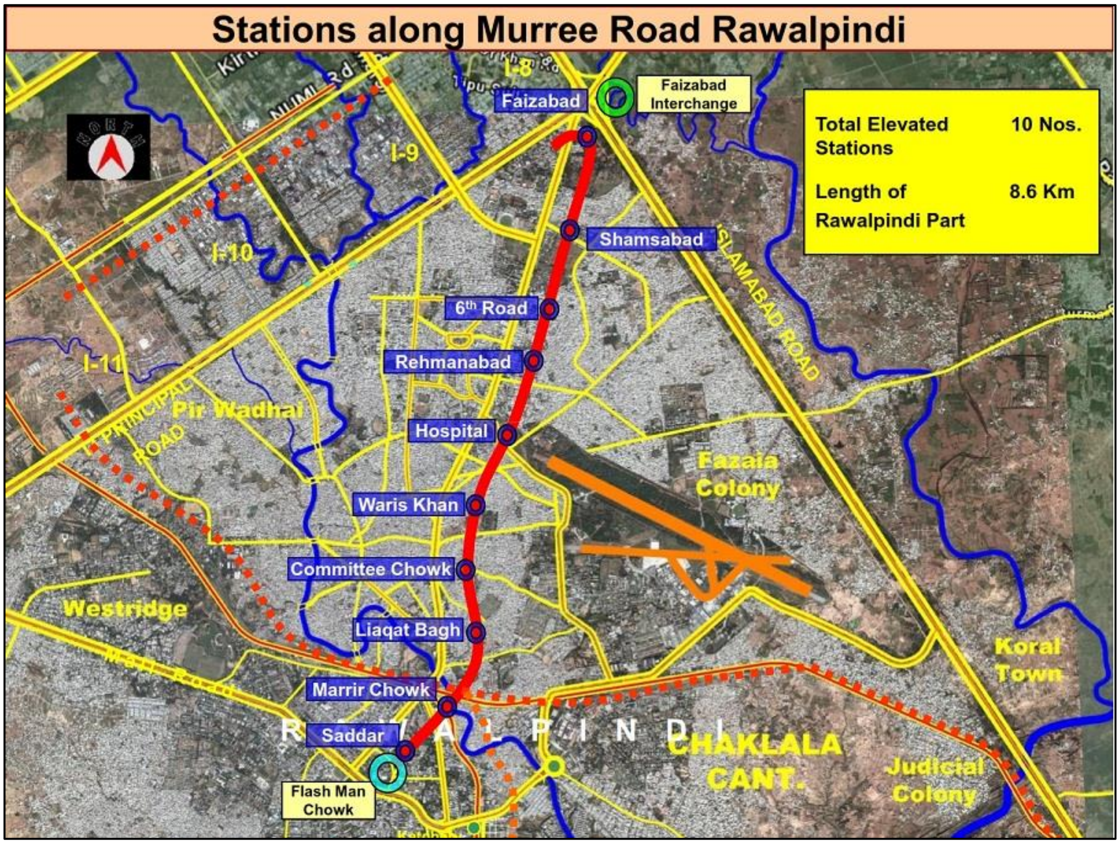

Figure 3.9: BRTS Stations along Murree road Rawalpindi

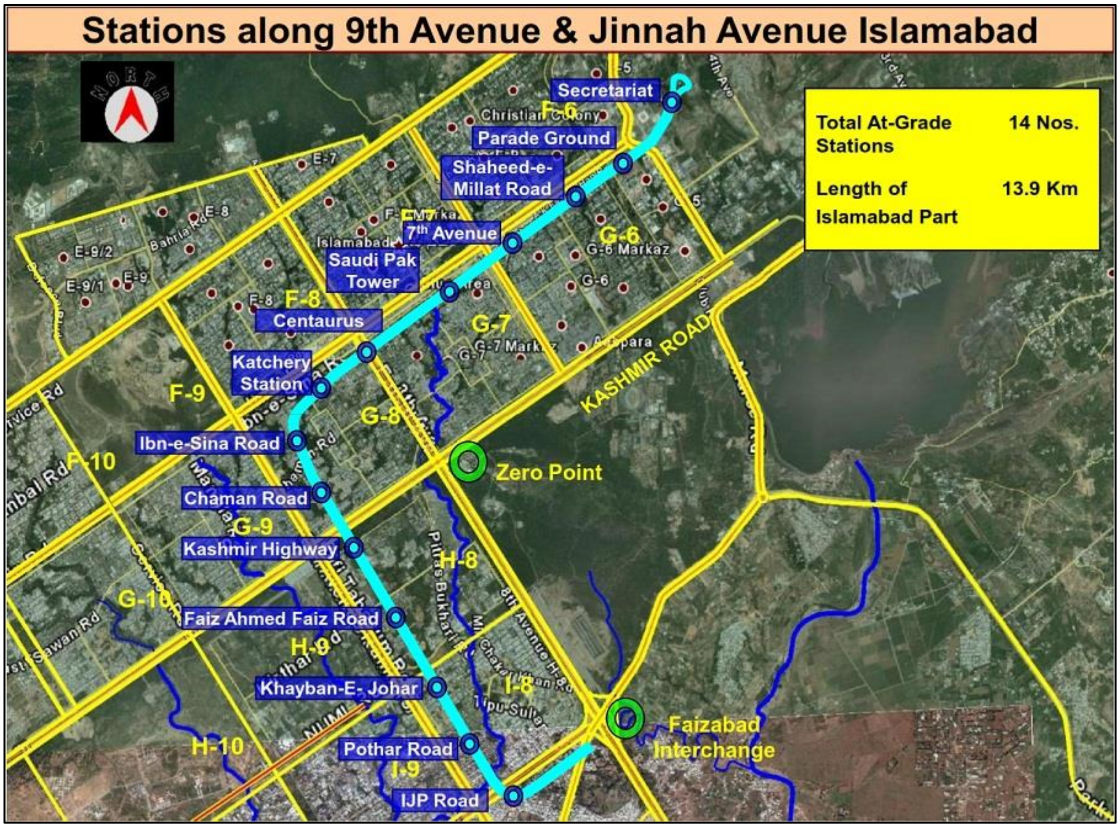

Figure 3.10: BRTS Stations along 9th Avenue & Jinnah Avenue Islamabad

To maintain randomness in the sampling and conducting survey, the questions were asked at all the randomly selected stations during different days of the week, and during different times of the day. It was also ensured that the questions must be asked from different age groups, gender and travelers with different socio-economic characteristics.

3.5.2. Secondary Data Collection

Secondary data is the data that is not collected directly by the user itself; rather this data has been collected by someone else. User now collects or obtains this data from a primary source and analyzes this data for to achieve the objectives of his study. The sources of secondary data include data obtained during literature review, censuses, organizational or institutional reports, data collected by different organizations, departments, authorities, journals, newspapers, libraries and books. Secondary data can also be obtained from previously carried out research studies. Secondary data has a basic advantage that it saves the time while conducting the survey or collecting data from a primary data collection method. Some other advantages of secondary data include that it usually comes as the processed data and so helps in the easier analysis, it needs lesser effort and lesser costs as compared to primary data.

The secondary data for this research study was collected from different departments and authorities. These include Punjab Metrobus Authority (PMBA), Capital development Authority (CDA) Islamabad, National Engineering Services of Pakistan (NESPAK) and Islamabad Safe City Project (ISCP). The data collected or obtained from these departments included economic data, travel time data, pre and post BRTS traffic counts data, geometric data, BRTS inventory data, BRTS operations data and BRTS ridership data. The obtained data were further analyzed for the travel time analysis, congestion analysis, vehicle operating cost (VOC) analysis, capacity analysis, safety analysis, environmental impact analysis and economic analysis of the BRTS Rawalpindi-Islamabad.

3.6. STATISTICAL TOOLS AND SOFTWARES USED

When the data is collected or obtained from any of the above discussed methods, then this data is analyzed using different softwares and statistical tools. Since the analysis for the study included four key parameters and a few number of sub-parameters, so the every parameter and the sub-parameters had a different method of analysis. The softwares used in the analysis framework included Microsoft (MS) Excel and Highway Capacity Software (HCS). Most of the analysis part was done using MS Excel. Data was organized, formatted and calculations were done with the help of formulas using the spreadsheet system of the MS Excel.

Highway Capacity Software (HCS) was used to analyze the congestion analysis of the system. HCS is a traffic analysis software and was incorporated to analyze the traffic condition before and after the implementation and operations of BRTS Rawalpindi-Islamabad. Murree road section of the BRTS was chosen to analyze the traffic congestion. The methodology adopted was first to analyze the traffic condition for pre-BRTS scenario, then to analyze the traffic condition for post-BRTS scenario. The comparison of pre and post BRTS implementation gave the assessed situation of traffic. HCS requires the data of peak hour traffic volume, PHF, peak 15 minute volume, road geometry characteristics, free flow speed, and adjustment factors for highway median, lateral clearance, Access points, presence of heavy vehicles etc. These adjustment factors were taken from highway capacity manual (HCM). The key indicator for the congestion analysis which the software gives is the Level of Service (LOS), which is a qualitative measure of traffic condition and quality on the roads and highways. LOS categorizes the traffic quality in six levels or conditions from LOS-A to LOS-F, where LOS-A indicates the best traffic flow condition whereas, LOS-F indicates the worst. The software also gives the results in terms of density of the road or highways section.

Simple linear regression analysis was also done as a statistical tool for the ridership demand analysis where the ridership was calculated as a function trip fare. A simple regression model was also developed for the said analysis. MS Excel was used for this analysis.

CHAPTER 4

4. ANALYSIS AND RESULTS

4.1. BACKGROUND

The trend of BRTS is increasing rapidly in the country, and of course, huge public money is involved in the construction of such mega projects, so it becomes necessary to evaluate such projects. In this research study, a post implementation evaluation has been carried out whose procedure is based on different performance measures/parameters/indicators. These performance measures include transportation impacts, environmental impacts, safety impacts and economic impacts. These are separately discussed below:

4.2. TRANSPORTATION IMPACTS

The transportation benefits of a good public transport service include affordable, reliable, safe, efficient and being environment friendly. A bus rapid transit service is designed with dedicated lanes for buses to provide all such facilities to the general public. In this evaluation process, the evaluation parameters to assess the transportation related benefits of BRTS Rawalpindi-Islamabad include Travel Time (TT) analysis, Vehicle operating cost VOC analysis, Traffic congestion analysis (LOS analysis), Modal shift analysis, Ridership demand analysis and Optimum fare calculation, Price elasticity of demand (PED) analysis and Capacity analysis. These parameters help in the evaluation of transportation impacts of BRTS Rawalpindi-Islamabad.

4.2.1. Travel time analysis:

Transportation interventions are always focused on providing reduced travel times to the general public. It is a common perspective of road users to adopt the mode or the route that consumes lesser travel time. This is the parameter which is always kept in consideration while choosing the route and the mode. The viability of any transportation service can be judged by the travel time that it takes to take its users to their destination.

Besides proving safe, economical, comfortable, and environment friendly transportation service, one of the very main focus of exclusive lane BRTS Rawalpindi-Islamabad was to provide the people a fast and rapid mean of urban transportation. So, the validity of this claim becomes far important. That's why the evaluation of BRTS travel time was to be carried out.

Analyzing travel time is a key performance measure in the evaluation framework of any public transport facility. This is done to analyze that how the BRT service has saved the travel time of its users who were previously using different modes to overcome their transportation needs. The analysis procedure in this regard was to collect travel time data of the commuters. Data for this purpose was collected from two main sources, i.e. from BRTS officials and through questionnaire survey. Actual current travel time data of the buses were collected from BRTS officials while the past travel time data and current travel times of the commuters was collected through a questionnaire survey. The real travel time was also calculated by travelling in the buses and noting down the travel time from station to station. Table 4.1 shows the actual travel times which were calculated by traveling in the BRTS buses.

Table 4.1: Actual station to station travel time

Sr. No.	Station	Travel Time (Min)	Sr. No.	Station	Travel Time (Min)
1	Secretariate	0:00	13	Potohar	25:22
2	P.Ground	2:55	14	IJP Road	27:30
3	S. Millat	4:11	15	F.Abad	29:51
4	7th Avenue	5:55	16	S. Abad	32:28
5	S. Exchange	8:56	17	6th Road	34:22
6	PIMS	11:21	18	R. Abad	36:16
7	Katchehry	13:12	19	C. Chowk	38:09
8	Ibn-e-Sina	15:23	20	W. Khan Road	40:31

9	Chaman Road	17:06	21	Committee Chowk	42:08
10	Kashmir H/way	18:41	22	L. Bagh	44:01
11	F.A Faiz	21:08	23	Marir Chowk	45:57
12	K-e-Johar	22:59	24	Sadar	47:52

It was a difficult task to get down the exact current travel times of the BRTS commuters. So, based on the literature review following procedure was adopted to get the current travel times. In this procedure, the current travel times of the BRTS users were calculated by asking two questions from the BRTS commuters: (i) the travel time from their origin to BRTS station, (ii) the travel time from BRTS station to their destination. This gives the out of vehicle travel time. Since the station to station travel times were previously calculated as given in table 4.1, and the commuters were also asked in the questionnaire survey about their BRTS origin and destination stations, the overall travel time was calculated by summing up all these travel times. This TT calculation procedure has been schematically shown as under in figure 4.1.

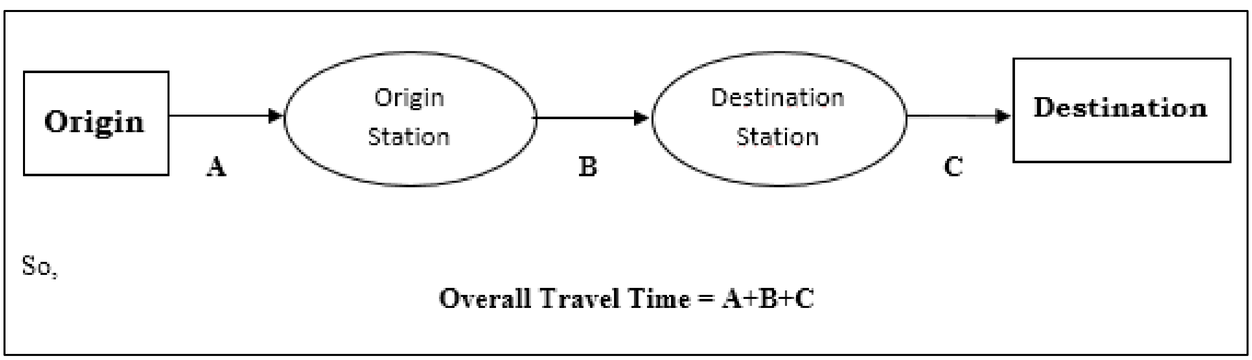

Figure 4.1: Schematic diagram showing the overall TT of the BRTS commuters

Using the above mentioned procedure, the current travel times of all the sampled users were calculated.

Next step was to calculate the previous travel time of the users when they used to travel before BRTS operations. So, for this purpose, based on literature, the previous travel time of the BRTS users was calculated by asking their previously used mode travel time. This TT included their origin to destination total travel time. In this way, the previous travel time of the BRTS users was calculated.

After knowing the travel times before and after the implementation of BRTS, the net travel time saving was calculated by subtracting the previous travel time from the current travel time of the users. Tables in the Appendix-A show this complete procedure of calculating the travel time. These travel time savings were then calculated for each of the mode from which the current BRTS commuters have been shifted. There were five shifted modes which include Public transport, Motor bike, Private Vehicle, Taxi and Rickshaw. Tables in the AppendixA-1, A-2, A-3, A-4 and A-5show the travel time savings of Public transport, Motor bike, Taxi, Own/Private Vehicle and Rickshaw respectively.

Based on the results, the commuters who have been shifted from public transport, their net travel time has been saved considerably. Out of the total sample, 113 BRTS users have been shifted from public transport and the total of 1373.39 minutes have been saved. This corresponds to a saving of 12.15 minutes per passenger.

Similarly for the commuters who have been shifted from Motor bike, their net travel time has been increased. Out of the total sample, 36 BRTS users have been shifted from Motor bike, and the total of 391.22 minutes have been increased. This corresponds to an increase of 10.87 minutes per passenger.

In the same way, for the commuters who have been shifted from private/Own vehicles, their net travel time has been increased. Out of the total sample, 24 BRTS users have been shifted from own vehicle, and the total of 327.68 minutes have been increased. This corresponds to an increase of 13.65 minutes per passenger.

For the commuters who have been shifted from Taxi, their net travel time has been increased. Out of the total sample, 25 BRTS users have been shifted from taxi, and the total of 207.42 minutes have been increased. This corresponds to an increase of 8.30 minutes per passenger.

And for the commuters who have been shifted from Rickshaw, their net travel time has also been increased. Out of the total sample, 7 BRTS users have been shifted from Rickshaw, and the total of 35.5 minutes have been increased. This corresponds to an increase of 5.07 minutes per passenger.

Above discussed results have been shown in the below table 4.2.

Table 4.2: Net travel time saving

Mode	**No. of commuters Shifted**	**Total TT saved/Increased (Minutes)**	**TT Saved/Increased per commuter (Minutes)**
Public Transport	113	1373.39	12.15
Motor Bike	36	-391.22	-10.87
Own vehicle	24	-327.68	-13.65
Taxi	25	-207.42	-8.30
Rickshaw	7	-35.5	-5.07
TOTAL	**205**	**411.57**	**2.01**

Net TT saving per commuter = 2.01 minutes

The results illustrate that only the travel time of the commuters who have been shifted from public transport has reduced. The commuters who have been shifted from Motor bike, Private Vehicles, Taxi and Rickshaw, their net travel time has increased. Further, it is incurred that the percentage of the commuters shifted from public transport is very high, this results in overall reduction in the travel time. The net TT saving of the sampled 205 commuters is 411.57 minutes. This makes the overall TT saving of 2.01 minutes per commuter.

Now, next step was to monetize this travel time saving by valuing the time. Value of travel time is the cost spent while travelling and not utilizing the time in some business or productive activity. Value of travel time analysis helps in evaluating the costs and benefits of a transportation intervention. So, to monetize the travel time savings of BRTS Rawalpindi-Islamabad, Wage Rate Method was used, which was given by ECONorthwest & Parsons (2002). In this method, the value of travel time is taken as the percentage of wage rate. This method considers the on-the-clock travel time and off-the-clock travel time. On-the-clock travel time is the time spent by doing some work or productive activity, while the off-the-clock travel time is the non-work time. ECONorthwest and Parsons Give the unit travel time values as a percentage of wage rate as given in below tables 4.3(a) and 4.3(b).

Table 4.3(a): Unit work TT value as %age of wage rate (Sinha & Labi, 2011)

Unit Work Travel-Time Values as a Percentage of Wage Rate

	Surface Modes[a]	Air Travel[a]	Truck Drivers
Local travel	100 (80–120)	NA	100
Intercity travel	100 (80–120)	100 (80–120)	100

Source: ECONorthwest and Parsons (2002).
[a] Values in parentheses indicate range. NA, not applicable.

Similarly non-work travel time values are given in below table.

Table 4.3(b): Unit non-work TT value as %age of wage rate(Sinha & Labi, 2011)

Unit Nonwork Travel-Time Values as a Percentage of Wage Rate

	Surface Modes[a]	Air Travel[a]	Truck Drivers
Local travel	50 (35–60)	NA	NA
Intercity travel	70 (60–90)	70 (60–90)	NA

Source: ECONorthwest and Parsons (2002).
[a] Values in parentheses indicate range. NA, not applicable.

Now to calculate the value of time for the BRTS Rawalpindi-Islamabad and for simplicity, a single value of wage rate was needed. Above tables give two values of wage rate for work travel time and non-work travel time. Since the BRTS is a surface mode and is a local travel facility, so the two values from the table came out to be 100% and 50%. The average of the two values gives a single travel time value as a percentage of wage rate i.e. 75%.

Next step in the monetizing of travel time was to determine the average wage rate. The average wage rates of Pakistan were obtained from a study, “Pakistan’s Wage Structure”, carried out by a Professor of Economics of International Islamic University Islamabad(Irfan, 2008). The author gives the Average Monthly Nominal Wages by Gender and by Industry from year 1990/91–2006/07 in tabulated form which has been attached as appendix B. From the table the Average Monthly Nominal Wage for the year 2006-2007 came out to be PKR 5983.69. This 2006-2007 year Rupees had to be brought to 2016 Pakistani Rupees. This was done by Cost adjustment method by multiplying the ratio of Consumer Price Indexes (CPI) of analysis year and the base year to the cost of base year. The analysis year and base year CPI values were taken from Pakistan Bureau of Statistics (PBS), presented as Appendix C and these values are as follows;

CPI of Base year (2006) = I_{BY} = 107.92

CPI of Analysis year (2016) = I_{AY} = 210.57

Cost of Base year (2006) = C_{BY} = 5983.69

So, the cost in analysis year is;

$C_{AY} = C_{BY} \times (I_{AY} / I_{BY})$

$$C_{AY} = 5983.69 \times (210.57 / 107.92)$$

$$C_{AY} = 11675.18 \text{ Rs/Month.}$$

$$C_{AY} = 11675.18 / 30$$

$$\mathbf{C_{AY} = 389.2 \text{ Rs/day.}}$$

The above value is the unit wage rate per day of Pakistan. The Unit travel time value as percentage of unit wage rate, which was already determined from the above table came out to be 75%. Now, the product of Unit wage rate percentage of Wage Rate (WR) gave the Unit travel time value, calculated below;

Unit travel time value = Wage Rate x TT value as Percentage of WR

Unit travel time value = 389.2x 0.75

Unit travel time value = 292 Rs/day

The above equation gave the unit travel time value. Travel time savings (minutes) had already been calculated. So, the product of travel time value, travel time saving (minutes), and the number of commuters gave the overall travel time saving in monetary terms as shown below.

Travel time saving (Rs) = Unit travel time value x Travel time saving(hours) x No. of commuters

Travel time saving (Rs) = 292 x (2.01/60) x 110652 x 365

Travel time saving (Rs) = 395,075,220.36 Rs. /year

Travel time saving = Rs. 395.07 Million Rs. /year

This shows that the BRTS has proved to be a good intervention in reducing the travel time and at the same time provides an economical way of public transportation. A total of 395.07 million rupees have been saved annually in terms of saving the time which people had to take while using the other modes before the implementation of BRTS Rawalpindi-Islamabad.

4.2.2. Vehicle Operating Cost (VOC) Analysis

Cost is one of the primary elements that people consider while choosing any mode of transportation. People always prefer the mode that costs lower provided that the other services are also up to satisfactory level. Vehicle costs are categorized as Fixed and Variable costs. Fixed costs include vehicle ownership, Vehicle registration cost and vehicle insurance etc. and are independent of vehicle operating costs and doesn't change due to any transportation improvement work. Variable costs are the expenses which directly influence the vehicle operating cost (VOC) and are varied with the use of vehicle. These costs include Fuel, lubricants, tire wear and tear, vehicle maintenance and vehicle cleaning costs. VOC increases due to many reasons, such as due to congestion, where the fuel consumption rate increases. Other reasons include poor road condition, which prone the vehicle to depreciation and tires wear and tear. Transportation improvement works help in minimizing these costs.

Bus Rapid Transit System is a good intervention to help reduce these costs by reducing the number of vehicles on the roads. Once the number of vehicles get reduced, the LOS of service on the roads gets improved, which ultimately minimizes the vehicle operating costs.

So, to assess the suitably of BRTS Rawalpindi-Islamabad on the basis of reducing the vehicle operating cost (VOC), the VOC impact analysis was carried out. This approach needs average daily traffic (ADT) of before and after BRTS operation. The traffic data on Murree road after the BRTS implementation was counted from the videos taken from the Islamabad safe city project shown in table as the Appendix D-01. The ADT before BRTS operations was taken from the NESPAK who carried out a Manually Classified Count (MCC) for the consultancy services of

BRTS Rawalpindi-Islamabad. The MCC was carried out in March 2014. To make the analysis simple and compatible, these traffic counts were brought to the year 2017 by applying a growth rate of 3% per year. These traffic counts have been shown in table as the Appendix D-02.

After computing the daily traffic, a unit VOC value was to be determined. For unit VOC determination "Hepburn model" was used. In 1994, for city highways, Hepburn developed a VOC model which encompasses fuel, tires, maintenance and vehicle depreciation as VOC elements as a function of two of VOC factors as speed and vehicle class. This model is useful to evaluate the VOC impacts of a transportation improvement work such as change in operating speed of vehicles or policies that result in a modal shift. Hepburn model is as under;

For "low" average travel speeds (<50 mph) : $$\text{VOC} = C + \frac{D}{S}$$

For "high" average
speeds (>50

Where VOC is in cents/mile, *S* is speed in mph, and *C, D,* a_0, a_1 *and* a_2 are the coefficients that are functions of vehicle class. These coefficient values are provided in table 4.4.

Table 4.4: Hepburn Model Parameters (Sinha & Labi, 2011)

Parameters for Hepburn's VOC–Speed Model					
Vehicle Type	C	D	a_0	a_1	a_2
Small automobile	24.8	45.5	27.2	0.035	0.00021
Medium-sized automobile	28.5	95.3	33.5	0.058	0.00029
Large automobile	29.8	163.4	38.1	0.093	0.00033

The speeds on the Murree road, IJP road, Jinnah road were taken from a study conducted by NESPAK and the average of these was calculated which came out to be 20 mph. Hence, the model for "Low" average travel speed was used. The traffic on Murree road is mix of small, medium and large vehicles, with the medium sized vehicles have the major contribution. So for the simplicity, it was assumed that the traffic on the analysis segment consist of medium sized automobiles (C = 28.5, D = 95.3). The unit VOC value from the Hepburn model was calculated as given below;

Unit VOC = C + D / S

Unit VOC = 28.5 + 95.3 / 20

Unit VOC = 33.27 cents/mile

After these, the vehicle miles travelled (VMT) was to be calculated. It was done by multiplying the ADT with the analysis segment length. Product of VMT and unit VOC gave the daily VOC values. Similarly VOC values were calculated for both before and after the implementation of BRTS Rawalpindi-Islamabad. These calculations have been in below table 4.5.

Table 4.5: Annual VOCs Before and After BRTS

	Length (Miles)	**ADT (Veh/day)**	**VMT**	**Speed (mph)**	**Unit VOC (Cents/mile)**	**Unit VOC (Rs/mile)**	**Daily VOC (Million Rs/day)**	**Annual VOC (Million Rs/year)**
Before BRTS	5.38	94,854.00	510,314.52	20.00	33.27	35.26	17.99	6,567.86
After BRTS	5.38	82,153.00	441,983.14	20.00	33.27	35.26	15.58	5,688.42

From the table above, the net VOC savings were calculated by subtracting the VOCs after the implementation of BRTS from the VOCs before the implementation of BRTS as shown below;

Net VOC saving = VOCs before the BRTS - VOCs after the BRTS

Net VOC saving = 6,567.86 - 5,688.42

Net VOC saving = 879.44 Million Rs/year

These are the results based on the traffic data (ADT) on Murree road, which is 5.38 miles (8.6 Km). The total length of the BRTS route is 14.06 miles (22.5 Km). Since only the traffic data of Murree road was available, so it was assumed that due to the construction and operation of BRTS, the change in the traffic pattern throughout the BRTS route is similar. Now on the basis of this assumption, the reduction in VOC was calculated for a unit mile as shown below.

Unit mile VOC Saving = 879.44 / 5.38 = 163.46 Million rupees/mile/year

Above value gives the unit mile VOC saving. This unit VOC saving was then multiplied with the total length (14.06 miles) of the project to get the overall VOC savings due to BRTS implementation and operations. The overall VOC savings were calculated as shown below.

Overall VOC savings = Unit mile VOC Saving x Total Length

Overall VOC savings = 163.46 x 14.06

Overall VOC savings = 2,298.31 Million rupees / year

These results provide the evidence that the BRTS has reduced the vehicle operating cost of the users. And hence the BRTS has benefited the people while considering the vehicle operating costs.

4.2.3. Traffic congestion analysis (LOS analysis)

Traffic congestion is a condition where the traffic operations on the roads continuously get interrupted because of many reasons, such as the demand increases the capacity, a traffic incident, and poor road condition etc. Traffic congestion is characterized by increased travel times, reduced speeds, formation of vehicle queues and personal frustration. As we say that BRTS is a strategy to mitigate the traffic congestion. Traffic management system encourages the use of public transport services, carpooling and paid parking systems etc. to provide smooth traffic operations on the roads. One of the main goal of the implementation of BRT service was to reduce the traffic congestion on the roads. So, to check whether BRTS has proved the mitigation of congestion, it is important to check its applicability. For this reason, Murree road was chosen to analyze the traffic congestion. Murree road is a major route along which the BRTS route traverses.

The ADT before BRTS operations was taken from the NESPAK who carried out a Manually Classified Count (MCC) for the consultancy services of BRTS Rawalpindi-Islamabad. This MCC was carried out in March 2014. The traffic data on Murree road after the BRTS implementation was counted from the videos taken from the Islamabad Safe City Project.

The indicator used for the congestion analysis was the computation of Level of Service (LOS). LOS is a qualitative measure of road traffic condition and traffic characteristics. Highway Capacity Manual (HCM) defines six LOS for the assessment of road traffic services, lettered as LOS A to LOS F. LOS A describes the best operating traffic condition and F describes the worst condition of traffic flow.

To analyze the LOS on Murree road, Highway Capacity Software (HCS) was used. HCS requires the data of peak hour traffic volume, PHF, peak 15 minute volume, road geometry, free flow speed, and adjustment factors for highway median, lateral clearance, Access points, presence of heavy vehicles etc. These adjustment factors were taken from highway capacity manual (HCM). The required data for the HCS analysis of the Murree road before the implementation of BRTS has been shown below in the table 4.6.

Table 4.6: Required data for the HCS analysis (Before BRTS)

Direction 1		**Direction 2**	
Free Flow Speed	45 mph	Free Flow Speed	45 mph
Volume	4545 vph	Volume	2980 vph
PHF	90 %	PHF	90 %
Lanes	3 lanes	Lanes	3 lanes
Trucks & Buses	4 %	Trucks & Buses	5 %

The required data were run into the software. The software results have been shown below:

```
       HCS: Multilane Highways Release 3.1b


Sabir
NUST
Phone:                                    Fax:
E-mail:

___________________________OPERATIONAL ANALYSIS________________________________

Highway:         Murree Road
Analyst:         Muhammad Sabir
From/To:         Murree Road
Analysis Year:   2014
Length:          5.4
```

Date: 3/27/2017

FREE-FLOW SPEED

Direction	1		2	
Free-Flow Speed:	Ideal		Ideal	
FFS or FFSi	45.0	mph	45.0	mph
Median Type	Divided		Divided	
Median Type Adjustment, FM	0.0	mph	0.0	mph
Lane Width	11.0	ft	11.0	ft
Lane Width Adjustment, FLW	1.9	mph	1.9	mph
Lateral Clearance:				
Right Edge	2.0	ft	2.0	ft
Left Edge	0.5	ft	0.5	ft
Total Lateral Clearance	2.5	ft	2.5	ft
Lateral Clearance Adjustment, FLC	2.5	mph	2.5	mph
Access Points per Mile	10		10	
Access Points Adjustment, FA	2.5	mph	2.5	mph
Adjusted Free-Flow Speed	38.1	mph	38.1	mph

VOLUME

Direction	1		2	
Volume, V	4545	vph	2980	vph
Peak-Hour Factor, PHF	0.90		0.90	
Peak 15-Minute Volume, v15	1263		828	
Number of Lanes	3		3	
Terrain Type	Level		Level	
Grade	0.00	%	0.00	%
Segment Length	0.00	mi	0.00	mi
Trucks and Buses	4	%	5	%
Trucks and Buses PCE, ET	1.5		1.5	
Recreational Vehicles	0	%	0	%
Recreational Vehicles PCE, ER	1.2		1.2	
Heavy Vehicle Adjustment, fHV	0.98		0.98	
Driver Population Adjustment, fP	1.00		1.00	
Service Flow Rate, vp	1717	pcphpl	1131	pcphpl

RESULTS

Direction	1		2	
Service Flow Rate, vp	1717	pcphpl	1131	pcphpl
Adjusted Free-Flow Speed, FFS	38.1	mph	38.1	mph
Avg. Passenger-Car Travel Speed, S	36.1	mph	38.1	mph
Level of Service, LOS	F		D	
Density, D	47.6	pc/mi/ln	29.7	pc/mi/ln

These software results show that the LOS of direction-1 is LOS-F. This is an indication that the traffic condition is worst during the peak hour flow. The demand is much higher than the capacity and needs some traffic improvement works. The direction-2 has the LOS-D, which indicates that the traffic is approaching to unstable and irregular flow and speeds of the vehicle start decreasing.

Similarly the same procedure was adopted for the post BRTS assessment. The required data shown in table 4.7 were put into the software and the results of the software have been shown below:

Table 4.7: Required data for the HCS analysis (After BRTS)

Direction 1		**Direction 2**	
Free Flow Speed	45 mph	Free Flow Speed	45 mph
Volume	4277 vph	Volume	2713 vph
PHF	90 %	PHF	90 %
Lanes	3 lanes	Lanes	3 lanes
Trucks & Buses	4 %	Trucks & Buses	5 %

The results of the post BRTS software analysis has been shown below:

```
                        HCS: Multilane Highways Release 3.1b


Sabir
NUST
123
123
123
Phone:                                        Fax:
E-mail:

___________________________OPERATIONAL ANALYSIS________________________________

Highway:        Murree Road
Analyst:        Muhammad Sabir
From/To:        Murree Road
Analysis Year:  2017
Length:         5.4
Date:           3/27/2017

_______________________________FREE-FLOW SPEED_________________________________

                   Direction           1                  2
Free-Flow Speed:                     Ideal              Ideal
     FFS or FFSi                     45.0      mph      45.0      mph
Median Type                          Divided            Divided
Median Type Adjustment, FM           0.0       mph      0.0       mph
Lane Width                           11.0      ft       11.0      ft
Lane Width Adjustment, FLW           1.9       mph      1.9       mph
Lateral Clearance:
     Right Edge                      2.0       ft       2.0       ft
```

Left Edge	0.5	ft	0.5	ft
Total Lateral Clearance	2.5	ft	2.5	ft
Lateral Clearance Adjustment, FLC	2.5	mph	2.5	mph
Access Points per Mile	8		8	
Access Points Adjustment, FA	2.0	mph	2.0	mph
Adjusted Free-Flow Speed	38.6	mph	38.6	mph

VOLUME

Direction	1		2	
Volume, V	4277	vph	2713	vph
Peak-Hour Factor, PHF	0.90		0.90	
Peak 15-Minute Volume, v15	1189		754	
Number of Lanes	3		3	
Terrain Type	Level		Level	
Grade	0.00	%	0.00	%
Segment Length	0.00	mi	0.00	mi
Trucks and Buses	4	%	5	%
Trucks and Buses PCE, ET	1.5		1.5	
Recreational Vehicles	0	%	0	%
Recreational Vehicles PCE, ER	1.2		1.2	
Heavy Vehicle Adjustment, fHV	0.98		0.98	
Driver Population Adjustment, fP	1.00		1.00	
Service Flow Rate, vp	1616	pcphpl	1030	pcphpl

RESULTS

Direction	1		2	
Service Flow Rate, vp	1616	pcphpl	1030	pcphpl
Adjusted Free-Flow Speed, FFS	38.6	mph	38.6	mph
Avg. Passenger-Car Travel Speed, S	37.2	mph	38.6	mph
Level of Service, LOS	E		C	
Density, D	43.4	pc/mi/ln	26.7	pc/mi/ln

Again these software results show that the LOS of direction-1 is LOS-E. This is an indication that the traffic condition is approaching worst during the peak hour flow. The demand is higher than the capacity and some traffic improvement works are suggested. The direction-2 has the LOS-C, which indicates that the traffic flow is steady and speeds of the vehicle start decreasing but still manageable.

So, the comparison of these results illustrate that the bus rapid transit system has improved the traffic flow on the roads and has helped in the mitigation of congestion. The LOS and the traffic density on the direction-1 road were LOS-F and 47.6 pc/mi/ln respectively, which have been improved to LOS-E and the density of 43.4 pc/mi/ln. Similarly the LOS and the traffic density on the direction-2 road were LOS-D and 29.7 pc/mi/ln respectively, which have been improved to LOS-C and the density of 26.7 pc/mi/ln.

These results validate the claim that BRTS is a congestion relief strategy by reducing the congestion and has facilitated the smoother flow of traffic on the roads.

4.2.4. Modal Shift analysis

Modal transfer occurs when there are one or more modes in competition and people prefer the mode based on different parameters, such as economy, reduced travel time, comfort, reliability etc. A bus rapid transit system is meant to provide these services better than the other modes in competition. One of the key objectives of the construction of BRTS was to discourage the use of private vehicles and to encourage the people to use the mass transit i.e. BRTS. Hence it becomes an essential tool in the evaluation framework to know the pattern of the people who have been shifted from different modes to BRTS.

The data to analyze the pattern of Modal shift was collected through the questionnaire survey. The questions were asked from the BRTS commuters about their previous mode of transportation or the mode they would be using if there were no BRTS service. Results suggest that the maximum number of commuters, who have been shifted to BRTS, previously were using the public transport. The public transport mainly consist of mini buses, wagons, Suzuki Vans, Chingchi’s etc. The condition of these services is very poor and taking much time to reach the destination. From a total of 385 surveyed commuters, 222 of them have been shifted from public transport. This corresponds to a percentage of 57.66%. This indicates that the highest number of people, who have been shifted to BRTS, were using existing public transport. This shift in the mode validates the fact that is the existing public transport service is in a poor condition, and BRTS has been proved to be a major improvement in the field of mass transit service. The second number of people who have been shifted to BRTS are from Motor bikes. A percentage of 18.70% of current commuters of BRTS previously were using Motor bike to fulfill their needs to transport. The people who been shifted from the taxis have a percentage shift of 10.91%. The people who were using their own private vehicles as their mode of transport, and currently using BRTS as their mode have a percentage shift of 9.87%. A small number of people who used Rickshaws as their mode of transportation, and now shifted to bus rapid transit service have a percentage shift of 2.86%. The findings of the survey and the above discussed results have been tabulated in the table 4.8.

Table 4.8: Percentage of Modal shift

Sr. No:	Previous Mode	Current Mode	Total No of trips shifted	%age shifted
1	Public transport	BRTS	222	57.66
2	Motor bike	BRTS	72	18.70
3	Taxi	BRTS	42	10.91
4	Own vehicle	BRTS	38	9.87
5	Auto Rickshaw	BRTS	11	2.86
			Total = 385	**100.00**

These results have also been shown in figure 4.2.

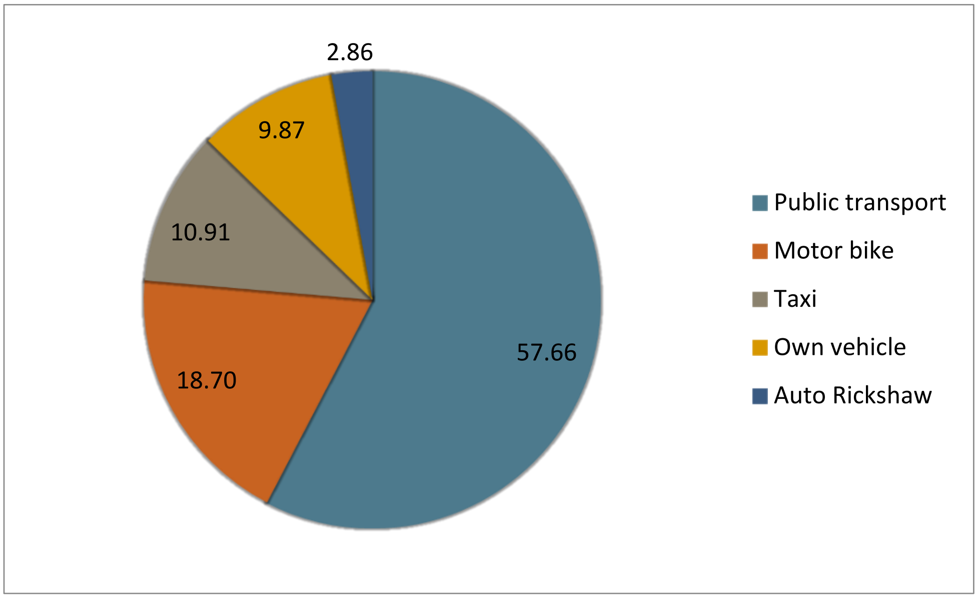

Figure 4.2: Shifted Modal share

This can be easily interpreted from the above figure that the public transport users have been shifted to BRTS, have the highest number. This relates that the existing public transport services were not up to the mark. This also indicates that the BRTS has proved to be a major improvement in this regard. 18.70% Motor bikes, 10.90% Taxis, 9.87% private vehicles, and 2.86% Rickshaws plying on the roads have been reduced. This indicates that the BRTS has also proved to mitigate the congestion which is one of its major objectives of construction and implementation.

4.2.5. Ridership Demand Analysis, Optimum Fare Calculation and Price Elasticity of Demand

These three parameters have been discussed separately and are as given below.

4.2.5.1. Ridership Demand Analysis

Transportation demand is the number of trips that people make to overcome their transportation needs and complete their socio-economic activities. The demand for any particular transportation service or facility depends on the socio-economic characteristics of the people as well as the physical transportation facilities, Operational conditions, service attributes and the related government policies. For the estimation of transportation demand, the most common variable is trip price/fare. Transportation demand is very sensitive to trip price. As the trip price increases, the demand falls. This is called “Law of Demand”.

Benefits of a good public transport include economical, reliable, comfortable, safe, and environmentally compatible etc. Generally these benefits can be seen as how the public transport attracts the people and what is its ridership demand. The ridership demand of the any mass transit service increases as it gets connected to feeder routes. Since the BRTS Rawalpindi-Islamabad has no specialized feeder routes, that’s why its ridership has been marked lower from its initially calculated values. The fare of the public transport also affects ridership. People prefer travelling mass transit because of its lower fares. It is a general practice throughout the world that the public transport facilities are mostly subsidized, so same is the case for BRTS Rawalpindi-Islamabad.

To assess the BRTS ridership demand, a Willingness to Pay (WTP) survey was conducted. A total of 220 BRTS commuters were surveyed and asked their minimum fare, they are willing to pay to use the BRTS services. Almost all the commuters were satisfied with current fare level i.e. Rs. 20. Most of the commuters were still agreed to travel if the BRTS fare gets increase. The survey results have been shown in the table 4.9.

Table 4.9: WTP Survey Results

S. No	Fare	Surveyed Ridership Demand	%age	Real daily Ridership Demand. (110652)*
1	20	220	100.0	110652
2	25	210	95.5	105622
3	30	163	74.1	81983
4	35	106	48.2	53314
5	40	63	28.6	31687
6	50	23	10.5	11568
7	60	14	6.4	7041

* Average daily Ridership calculated by PMBA.

From these results it can be seen that as the fare increases, the demand gets decrease. Current average daily ridership was taken as 110,652 passengers per day corresponding to the current fare of Rs. 20, which was calculated by Punjab Metro bus Authority (PMBA). These results have been shown graphically in figure 4.3. This figure shows the relationship between fare and ridership/demand. The demand is maximum i.e. 110,652 Passengers/day when the fare is minimum i.e. Rs. 20. Similarly as the fare is increased, demand decreases.

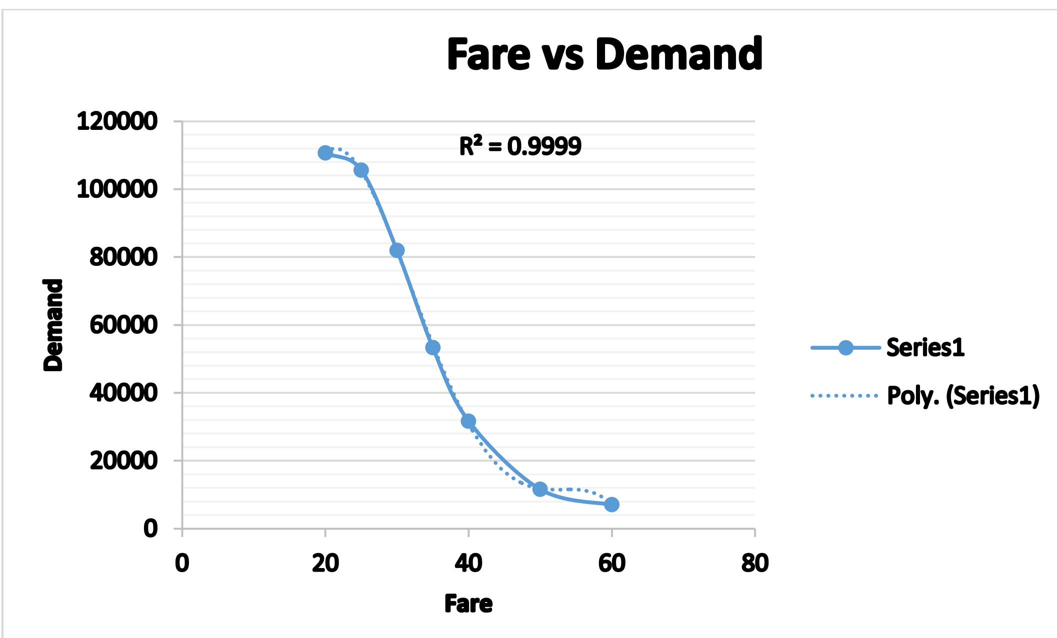

Figure 4.3: Relationship between Fare & Demand

A simple regression model was also developed to get the relationship between fare and demand. A very high value of coefficient of Determination, R-Squared ($R^2 = 0.99$) indicates that there is a strong relation between fare and ridership/demand. The demand is maximum when fare is minimum. This shows an inverse relation between these variables.

$$\mathbf{y = -0.298x^4 + 50.727x^3 - 3037.4x^2 + 71976x - 471915}$$

Where,

y = Ridership/demand (Passenger/day)
x = Fare (Rs.)

4.2.5.2. Optimum Fare Calculation

A public transport facility such as BRTS, MRT or any such facility is built to provide economical, comfortable, reliable and environment friendly mean of transport. This is a service provided by the Government to its public, that's why government agrees to provide a subsidy for this service or facility. Also, it is a general practice throughout the world that the public transport facilities are mostly subsidized, so same is the case with BRTS Rawalpindi-Islamabad.

A higher fare discourages the people to travel; resultantly a reduced ridership is experienced. Similarly a lower fare level maximizes the subsidy, which overburdens the government. Now the question arises that whether the current BRTS fare is reasonable or it should be increased or decreased. To assess this fare, the results of Willingness to pay (WTP) survey were further analyzed and revenue generation for each fare level was calculated as shown in table 4.10. The calculated daily ridership was multiplied with its corresponding fare level to get the daily Revenues.

Table 4.10: WTP Survey Ridership and Revenues

S. No	Fare	Surveyed Ridership Demand	%age	Real daily Ridership Demand.	Revenue (Rs/Day)
1	20	220	100.0	110652	22,13,040
2	25	210	95.5	105622	26,40,550
3	30	163	74.1	81983	24,59,490
4	35	106	48.2	53314	18,65,990
5	40	63	28.6	31687	12,67,480
6	50	23	10.5	11568	5,78,400
7	60	14	6.4	7041	4,22,460

The results suggest that the current BRTS fare i.e. Rs. 20 is of a lesser amount and the highest revenue can be generated when the fare is increased to Rs.25. Even if the fare is increased to Rs.30, still it gives more revenue than that of the current fare level. This relationship has been shown in figure 4.4. When the fare is increased to Rs.25, the revenue gets increased, but if the fare is increased further, the revenue starts declining. Hence, an optimum fare may be set up at Rs. 25.

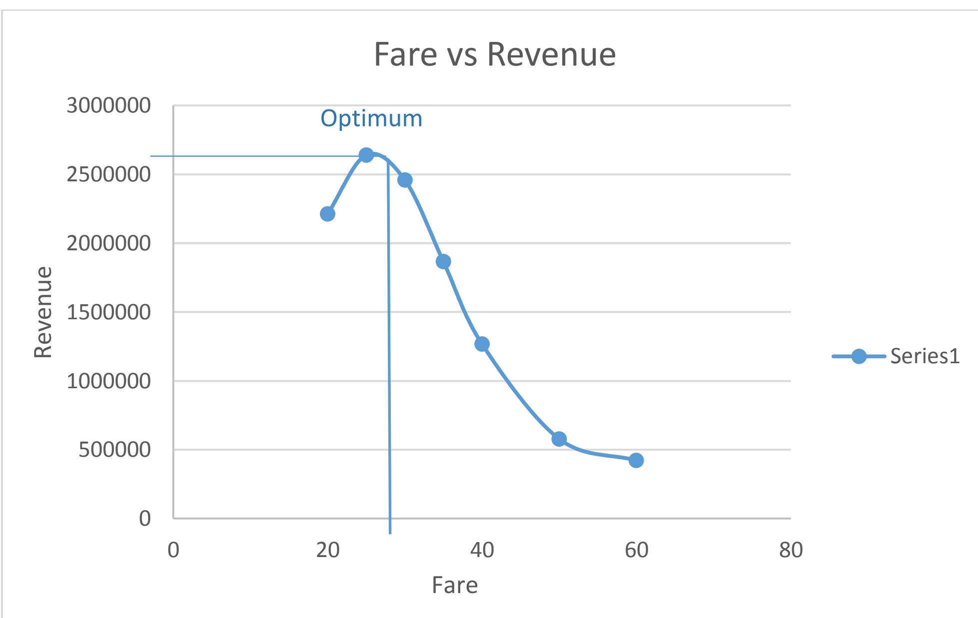

Figure 4.4: Relationship between Fare & Revenue

With this optimum fare, the generated revenue can be enhanced by Rs.4, 27,510 per day which corresponds to an enhanced revenue of Rs. 12.83 Million per month. This fare level will help minimizing the government provided subsidy while not causing the ridership to a higher level reduction.

4.2.5.3. Price Elasticity of Demand (PED) Analysis

Transportation demand is the number of trips that people make to overcome their transportation needs and complete their socio-economic activities. The demand for any particular transportation service or facility depends on the socio-economic characteristics of the people as well as the physical transportation facilities, operational conditions, service attributes and the related government policies. For the estimation of transportation demand, the most common variable is trip price/fare. Transportation demand is very sensitive to trip price. As the trip price increases, the demand falls.

To check this sensitivity, Price elasticity of demand (PED) analysis is used. Price elasticity of demand is used to determine the relationship between the percent changes in demand with respect to a percent change in its price. This can be further elaborated as that what is the sensitivity of demand when the price is changed by one unit. This is a check to the price sensitivity of any good or service. Mathematically it can be stated as;

Price elasticity of demand = % change in quantity demanded / % change in price

$$E_d = \frac{\%\_Change\_in\_demand}{\%\_Change\_in\_X}$$

$$E_d = \frac{Change\_in\_demand / Original\_demand}{Change\_in\_x / Original\_value\_of\_x}$$

$$E_d = \frac{\partial V / V}{\partial x / x} = \left(\frac{x}{V}\right)\left(\frac{\partial V}{\partial x}\right)$$

If a small change in price or fare of any goods or service results in a large change in its quantity demanded, then that good or service is said to be elastic. It describes that the good or service is sensitive to its price. On the contrary, when a major change in price produces a small change in its quantity demanded, then such goods or services are said to be inelastic. A product is unit elastic when the percentage change in price or fare is equal to the change in quantity demanded. This has been described in figure 4.5.

A good or service is said to be perfectly inelastic when its price elasticity of demand is equal to zero. It means that the changing the price does not affect the demand. A value of PED between zero and one shows that the demand is inelastic, which means that any change in price or fare produces a small change in demand. And any value of PED greater than one indicates that the demand for that good or service is perfectly elastic, which can be elaborated as a small change in price or fare produces a major change in its quantity demanded. This can be understood easily by the figure 4.5 below:

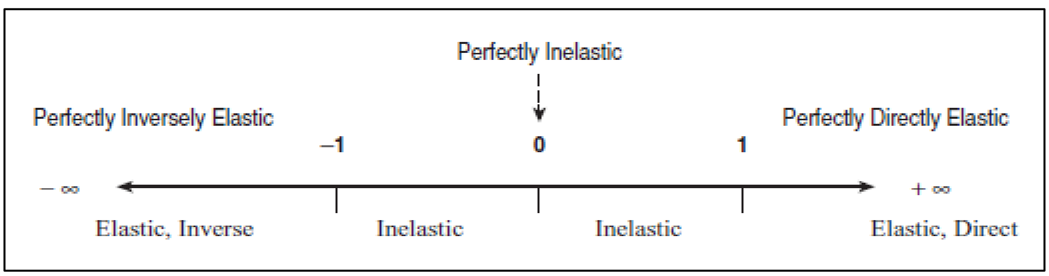

Figure 4.5: Elastic & Inelastic regions of PED (Sinha & Labi, 2011)

For the case of BRTS, which is a subsidized project, it becomes essential to determine that what happens when the fare is increased. The willingness to pay survey results were further analyzed and the price elasticity for each of the fare level was calculated. Table 4.11 shows these results.

Table 4.11: Price Elasticity of demand analysis

S. No	Fare	Surveyed Ridership Demand	%age	Real daily Ridership Demand.	Revenue (Rs/Day)	Price Elasticity of demand, (PED)
1	20	220	100.0	110652	22,13,040	0.18
2	25	210	95.5	105622	26,40,550	1.12
3	30	163	74.1	81983	24,59,490	2.10
4	35	106	48.2	53314	18,65,990	2.84
5	40	63	28.6	31687	12,67,480	2.54
6	50	23	10.5	11568	5,78,400	1.96

Figure 4.6 shows these results graphically.

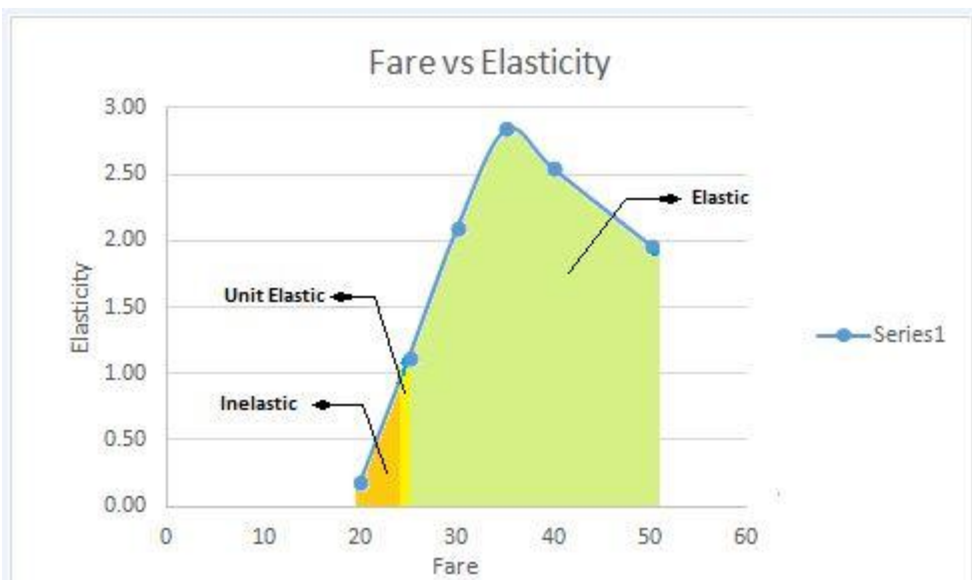

Figure 4.6: Relationship between Fare & Elasticity

These results show that the demand is inelastic when the fare is Rs. 20. And then as the fare increases the elasticity also gets increased. It further describes that as the fare approaches Rs. 25, this increase in price produces a small reduction in demand, since its PED value is nearer to unit elasticity. The value of elasticity is highest i.e. 2.84, when the fare is Rs. 35. This can be interpreted as if the fare is increased up to Rs.35, the ridership will decrease considerably. The results suggest that the current fare lies at a PED value of 0.18, where the demand is inelastic.

Hence, this is not a reasonable fare level. So, an increase in fare level up to Rs. 25 is recommended.

4.2.6. Capacity Analysis

Capacity of a BRTS bus can be defined as the maximum number of passengers that a bus can take. And the capacity of the entire system is the maximum number of passengers that can travel in the buses in unit time. Capacity analysis is one the important parameters to evaluate the transit system. Because any transit system is designed based on travel demand forecasting models as well as some feasibility reports, so, to assess that how the system has proved to provide the level of capacity for which it was designed, capacity analysis is the tool to evaluate the system capacity. This will also help in the decision making whether the currents system needs more buses, or the current number of buses need to be reduced. System capacity also provides indication regarding the comfort and reliability of the overall system. Thus it proves to be a vital performance indicator.

BRTS Rawalpindi-Islamabad was designed to provide a daily ridership of 1,35,000 passengers per day. And the system capacity was calculated to provide a maximum capacity of almost 1,90,000 passengers per day. To determine how much these demand objectives have been achieved, a capacity analysis was carried out. The daily hourly based ridership data was taken from Punjab Metro bus Authority (PMBA). The daily and the hourly maximum capacity ridership data was also taken from PMBA, which was noted to be 1,90,000 Passengers per day and 10,625 Passengers per hour respectively. Table 4.12 shows the results of this capacity analysis. Graphically a relationship between timing of the day and the V/C ratio has been shown in the figure 4.7.

Table 4.12: Volume to Capacity Ratio

Sr. No:	Time	Volume (Ridership) (Pas/hr/day)	Ridership max. capacity (Pas/hr/day)	V/C Ratio	V/C %age
1	< 6	71	10625	0.0067	0.67
2	6-7	1936	10625	0.1822	18.22
3	7-8	5715	10625	0.5379	53.79
4	8-9	7448	10625	0.7010	70.10
5	9-10	6742	10625	0.6345	63.45
6	10-11	6930	10625	0.6522	65.22
7	11-12	7633	10625	0.7184	71.84
8	12-13	8594	10625	0.8088	80.88
9	13-14	6361	10625	0.5987	59.87
10	14-15	7366	10625	0.6933	69.33
11	15-16	8624	10625	0.8117	81.17
12	16-17	9264	10625	0.8719	87.19
13	17-18	9961	10625	0.9375	93.75
14	18-19	8416	10625	0.7921	79.21
15	19-20	6759	10625	0.6361	63.61
16	20-21	5046	10625	0.4749	47.49
17	21-22	3535	10625	0.3327	33.27
18	22-23	251	10625	0.0236	2.36
TOTAL		**110652**	**191250**	**0.5786**	**57.86%**

These results suggest that the system is operating at a lower capacity level. The overall system operates at a volume to capacity ratio of 57.86%. This implies that the occupancy of BRTS buses is 57.86%. Furthermore, these results clearly define the peak and off peak hours and indicating the time between 5:00 PM to 6:00 PM as the peak hour where the V/C ratio is approaching 1.0 i.e. 0.937. Rest of the time the V/C ratio is far below an alarming V/C ratio of 1.0. This can be extracted

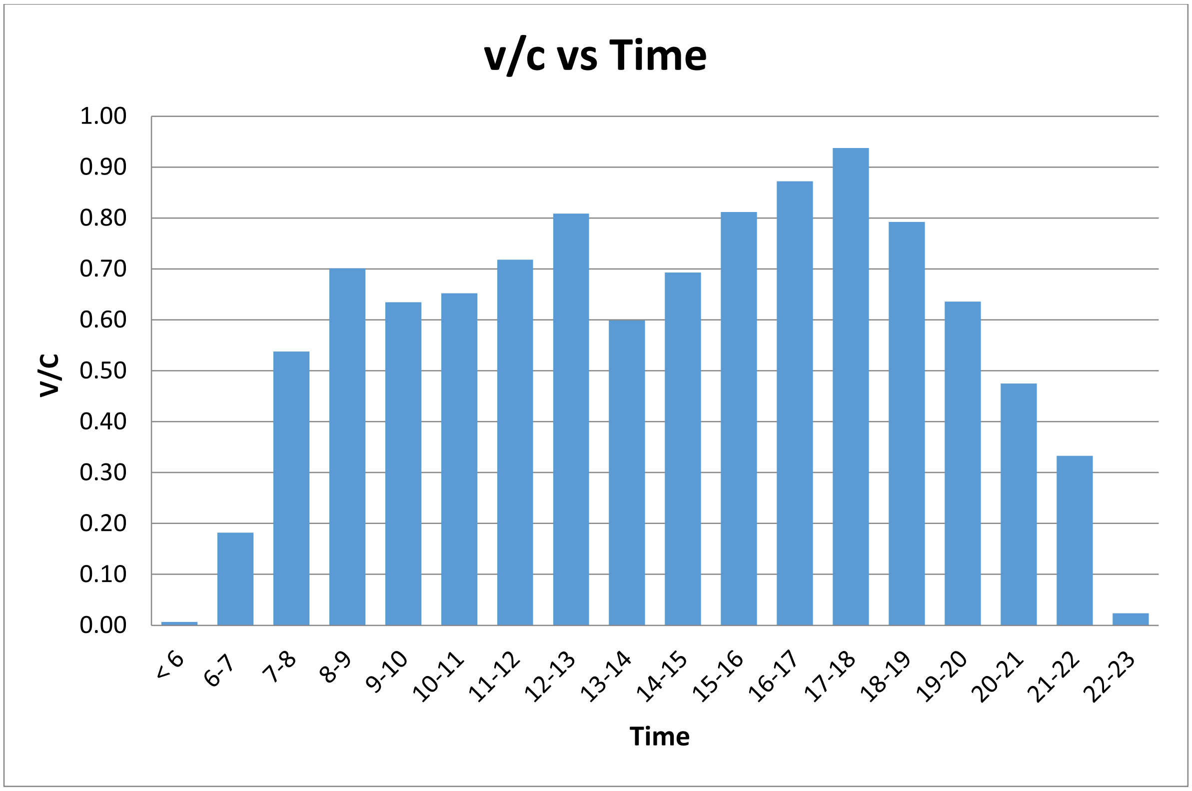

Figure 4.7: Relationship between V/C and Time

from these results that the number of buses is somewhat reasonable during the peak hours but it is very high during the off peak hours. So it is recommended that the number of buses may be used variably during the day. There is no need to increase the number of buses, but these may be reduced considerably during the off peak hours. This strategy will help in minimizing the subsidy being provided by the government.

4.3. SAFETY IMPACTS

In current years the provision for road safety has gained popularity. Fatalities due to road crashes have been increased considerably. It has been projected that road crash fatalities (RCF) will become the 5^{th} leading cause of worldwide premature deaths by 2030. According to different studies, globally 1.24 Million road crash fatalities and 30-50 Million non-fatal injuries (RCI) take place annually. This corresponds to 3,400 deaths and 82,300 non-fatal injuries per day. And 90% of these deaths and injuries take place in low or middle income countries. Economically these deaths and injuries cost over 600 Billion Dollars per annum. These numbers are decreasing in developed countries whereas increasing in developing and under developed countries.

In a developing country like Pakistan, National road safety secretariat (NRSS) reported 2 Million road traffic crashes in 2006. According to a study by World health organization (WHO) in 2010, 30,000 road crash fatalities took place in Pakistan. Fatmi et al., (2007) reported that 270,000 road crash injuries took place in the country. In Pakistan the road crash fatalities are the 11^{th} cause of premature fatalities and the road crash injuries are the second leading cause of disability. Economically the CRF and CRI costs over 3 Billion Dollars annually. These costs are borne by individuals, Government, and insurance agencies and are consist of tangible and intangible costs. Tangible costs include property damage, market productivity loss, household productivity loss and workplace costs. Intangible costs include loss of life and injuries. These statistics indicate an alarming situation and warrant some major improvements and interventions in the field of road traffic safety.

A bus rapid transit system is meant to provide fast, economical, affordable and at the same time safe transport to the public. Beside these characteristics, the impact of BRTS is equally important because it tends to be situated along major arterials of the city. A study was carried out in New York City and based on that city the urban arterials account for around 15% of the city road network, but account for over 65% of the road crashes. The BRTS is considered to be a positive intervention toward the safety of individual commuters as well as the overall network road crashes. So, the safety impacts assessment of the BRT system is important.

To analyze the safety impacts of BRTS, Murree road section was chosen, which is one of the principle urban arterials along which the BRTS route traverse. The approach was to estimate fatal and non-fatal crashes before and after the implementation of BRTS by using the crash rate factors (CRF) provided by US Federal Highway Authority (FHWA) as tabulated in table 4.13.

Table 4.13: Fatal and Non-fatal Crash Rates (Sinha & Labi, 2011)

Motor Vehicle Traffic Fatality and Injury Rates by Functional Class

		Number of Crashes (per 100 million VMT)	
Area Class	Functional Class	Fatal	Non-Fatal
Rural	Interstate	1.05	25.08
	Other principal arterial	1.96	50.87
	Minor arterial	2.33	70.52
	Major collector	2.51	86.79
	Minor collector	3.16	106.02
	Local	3.52	147.79
Urban	Interstate	0.56	46.56
	Other freeway & expressway	0.75	68.60
	Other principal arterial	1.30	124.69
	Minor arterial	1.08	126.89
	Collector	1.00	104.95
	Local	1.33	194.40

This approach needs average daily traffic (ADT) of before and after BRTS operation. The traffic data on Murree road after the BRTS implementation was counted from the videos taken from the Islamabad safe city project. The ADT before BRTS operations was taken from the NESPAK who carried out a Manually Classified Count (MCC) for the consultancy services of BRTS Rawalpindi-Islamabad. The MCC was carried out in March 2014. To make the analysis simple and compatible, these traffic counts were brought to the year 2017 by applying a growth rate of 3% per year.

Calculation of fatal and non-fatal crashes needs Vehicle miles travelled (VMT). The length of the Murree road is 5.38 miles and this length is multiplied with the ADT to get the Vehicle miles travelled. This VMT is then multiplied with the Crash rate factors (CRF) given in table 1.9 to get the fatal and non-fatal crashes. The functional classification of Murree road comes under the class of urban principle arterial. And from the table, the number of crashes per 100 million VMT for fatal and non-fatal crashes comes out to be 1.30 and 124.69 respectively. Multiplying the VMT with number of crashes gives the fatal and non-fatal crashes as given in table 4.14.

Table 4.14: Fatal and Non-fatal Crashes

	Length (Miles)	ADT (Veh/day)	VMT (per 100 million)	Fatal Crashes	Non-Fatal crashes
Before BRTS	5.38	94,854	1.863	2.421	232.254
After BRTS	5.38	82,153	1.613	2.097	201.155

After fatal and non-fatal crashes have been calculated, the crashes after the implementation of BRTS were then subtracted from the crashes before BRTS implementation. This gave the net reduction in fatal and non-fatal crashes as shown in table 4.16. These reductions in the crashes were then to bring into monetary terms. International road assessment program (iRAP) has worked on monetizing the fatal and non-fatal crashes (McMahon & Dahdah, 2008).In their paper “The true cost of road crashes, valuing life and cost of serious injuries”, the authors used the data of different countries and came up with some values to quantify the crashes based on different models incorporating different basic parameters such as Gross Domestic Product (GDP) of the country etc. In the end the authors presented the result of their model in the given below table 4.15.

Table 4.15: IRAP economic appraisal model values (Dahdah & McMahon, 2008)

	Lower Economy	**Middle Economy**	**Upper Economy**
Value of Fatality	60*GDP/Capita	70*GDP/Capita	80*GDP/Capita
Value of Injury	12*GDP/Capita (20% VSL)	17*GDP/Capita (25% VSL)	24*GDP/Capita (30% VSL)
Number of Serious Injuries to number of Fatalities	8	10	12

Based on the models, IRAP provides values for lower, middle and upper economy level countries and gives the values of fatalities and injuries. Pakistan being a middle economy level country, so the values for fatal crashes and injury crashes could be;

Value of fatal crashes = 70 *GDP/Capita

Value of non-fatal crashes (Injuries) = 17 * GDP/Capita

These are the general model based provided values which can be used for any country for quantifying the crashes. From Pakistan Bureau of Statistics (PBS), the GDP per capita of Pakistan for the year 2015-2016 is US $ 1513, which corresponds to PKR 162,568. The Dollar value for the current date is PKR 107.4. So, the unit fatality and injury rates can be:

Value of fatal crashes = 70 * 162,568 **= 11,379,760** (PKR)

Value of non-fatal crashes = 17 * 162,568 **= 2,763,656** (PKR)

The reductions in fatal and non-fatal crashes were then multiplied with the value of fatal and non-fatal crashes to get the net savings in their corresponding crashes. The results of these calculations have been shown in table 1.17.

Table 4.16: Safety savings

Reduction in Fatal Crashes	**Reduction in non-Fatal Crashes**	**Fatal Crashes cost saving** (Rupees per Year)	**Non-Fatal Crashes cost saving** (Rupees per year)	**Total Savings** (Rupees per year)
0.32	31.10	3,689,686.87	85,946,592.95	89,636,279.83

From these results, it is intimated that the claim that BRTS accounts for the safety improvement of the system, the claim is valid. BRTS has reduced the number of fatal and non-fatal crashes and hence if these reductions are put into monetary terms, it is stated that after the implementation of BRTS, the system has saved Rs. 3,689,686.87 and Rs. 85,946,592.95 for of fatal and non-fatal crashes respectively. The total saving becomes Rs. 89,636,279.83.

These are the results based on the traffic data (ADT) on Murree road, which is 5.38 miles (8.6 Km). The total length of the BRTS route is 14.06 miles (22.5 Km). Since only the traffic data of Murree road was available, so it was assumed that due to the construction and operation of BRTS, the change in the traffic pattern throughout the BRTS route is similar. Now on the basis of this assumption, the reduction in fatal and non-fatal crashes was calculated for a unit mile as shown below.

Unit mile fatal crashes Savings = 3,689,686.87 / 5.38 = 685,815.24 Rupees/mile/Year

Unit mile non-fatal crash savings = 85,946,592.95 / 5.38 = 15,975,203.15 Rupees/mile/Year

Above values give the unit mile crash cost savings for fatal and non-fatal crashes. These unit crash cost savings were then multiplied with the total length of the project to get the overall safety cost savings due to BRTS implementation and operations as shown in table 4.17.

Table 4.17: Overall Safety savings

Unit mile fatal Crashes cost saving (Rupees per Year)	**Unit mile non-fatal Crashes cost saving** (Rupees per Year)	**Overall fatal Crashes cost saving** (Rupees per Year)	**Overall non-fatal Crashes cost saving** (Rupees per Year)	**Total Crash cost Savings** (Rupees per Year) (2017)
685,815.40	15,975,203.15	9,642,564.58	224,611,356.30	**234,253,920.89**

The results shown in above table suggest that the BRTS has proven to be a good intervention to improve the road safety. A net saving of Rs. 234.25 million per year has been saved due to the implementation of BRTS in respect of road safety.

4.4. ENVIRONMENTAL IMPACTS

Environmental pollution is becoming a global hazard and almost every part of the globe is being affected by this. A pollutant is a gaseous, solid or liquid particle which causes adverse impacts on plants, animals, climate and other properties, if it is dispersed and exposed directly to environment. This pollution to environment is increasing with each passing day. And hence it has created an alarming situation for everyone who is involved in any decision making.

Transportation is a mobile source of air and noise pollution which has project and network level as well as global impacts. The transportation sector is a major user and burns the most of world's petroleum. Transportation vehicles emit carbon mono oxides, oxides of Sulfur and Nitrogen, organic compounds and other toxic chemicals that not only affect human health but also have adverse and negative impacts on climate, fauna, flora, rivers and lakes. Based on a study conducted by US Environmental protection agency on a data of last 10 years, the transportation sector contributed about 84% Carbon monoxide CO, 52% of oxides of Nitrogen NOx, and 45% of Volatile organic compounds VOC emissions in the country (USEPA, 2005).

The transportation projects not only provide mobility, accessibility and socio-economic development but at the same time these projects have adverse impacts on environment. These impacts may be short term as well as long term. Short term impacts include the construction period when dust, pollution and noise disturb the environment. Long term impacts include the post construction period where the environment is continuously disturbed by transportation vehicles which emit environmentally hazard and harmful air pollutants. That's why environmental regulatory bodies insist to carry out environmental impact assessments (EIA) for such projects.

Projects like Bus Rapid Transit System (BRTS) mean not only to provide transportation related facilities but also aim to reduce the emissions and help in providing environment friendly transportation services. As discussed earlier, BRTS project has helped in reducing the congestion and improved the LOS, so the flow of vehicles has also become smoother and the speed has increased. This increased speed also causes a reduction in pollutants emitted from the vehicles. BRTS projects have also proved to be environment friendly throughout the world because these projects discourage the use to conventional buses and private vehicles which result in reduced number of vehicles on the roads (VMT) and at the same time the quality of BRTS buses are far better than those of other conventional public transport buses.

To check whether these assumptions are valid or not, an evaluation process was carried out. In this procedure, first the vehicle miles travelled (VMT) was to calculate. ADT was previously calculated and the project length on Murree road was known, so the VMT was calculated by multiplying the length with ADT. Transit Cooperative Research Program (TCRP) gives the emissions by mode of different air pollutants as shown in table 4.18. The product of VMT and the corresponding air pollutant emission value gives the total emissions of the particular air pollutant.

Table 4.18: Pollution Emissions by type of Vehicle (Sinha & Labi, 2011)

Pollution Emissions by Mode (g/VMT)

	VOC	CO	NO_x	CO_2
Automobile	1.88	19.36	1.41	415.49
SUVs, light truck	2.51	25.29	1.84	521.63
Bus	2.3	11.6	11.9	2386.9
Diesel-powered rail	9.2	47.6	48.8	9771.0

Following the above mentioned procedure, the emissions for each of the air pollutant were calculated for before BRTS implementation scenario as given in table 4.19.

Table 4.19: Pollution Emissions before BRTS

Length (Miles)	**ADT** (Veh/day)	**VMT**	**VOC** (Kg)	**CO** (Kg)	**NOx** (Kg)	$\mathbf{CO_2}$ (Kg)
5.38	94,362.00	507,667.56	954.42	9,828.44	715.81	210,930.79

Similarly, the emissions for each of the air pollutant were calculated for post BRTS implementation scenario as shown in table 4.20.

Table 4.20: Pollution Emissions after BRTS

Length (Miles)	**ADT** (Veh/day)	**VMT**	**VOC** (Kg)	**CO** (Kg)	**NOx** (Kg)	$\mathbf{CO_2}$ (Kg)
5.38	81,526.00	438,609.88	824.59	8,491.49	618.44	182,238.02

Once the air pollutant emission values for both before and after the implementation of BRTS were known then the net reduction in environmental pollutions were calculated by subtracting the post BRTS scenario emissions from the pre BRTS scenario emissions. These results have been shown in table 4.21.

Table 4.21: savings in Pollution Emissions

Pollutants	Reduced Emissions		
	Kg/day	Kg/year	Tons/year
VOC	129.83	47,387.38	47.39
CO	1,336.96	487,989.19	487.99
NOx	97.37	35,540.54	35.54
CO_2	28,692.78	10,472,863.04	10,472.86
Total	**30,256.93**	**11,043,780.15**	**11,043.78**

These are the results based on the traffic data (ADT) on Murree road, which is 5.38 miles (8.6 Km). The total length of the BRTS route is 14.06 miles (22.5 Km). Since only the traffic data of Murree road was available, so it was assumed that due to the construction and operation of BRTS, the change in the traffic pattern throughout the BRTS route is similar. Now on the basis of this assumption, the reduction in the air pollution emission was calculated for a unit mile as shown below.

VOC = 47.39/5.38 = **8.81** tons/year/Km

CO = 487.99/5.38 **= 90.70** tons/year/Km

NO_x = 35.54/5.38 **= 6.61** tons/year/Km

CO_2 = 10,472.86/5.38 **= 1946.47** tons/year/Km

After determining the emission reductions for a unit mile, the overall reduction in emissions was calculated by multiplying the value of unit mile emission reduction with the overall length of BRTS route. These are shown in below table 4.22.

Table 4.22: Overall Savings in Pollution Emissions

Pollutants	Reduced Emissions	
	Tons/year/Km	Tons/year
VOC	8.81	123.84
CO	90.70	1,275.30
NO_x	6.61	92.88
CO_2	1,946.63	27,369.60
Total		**28,861.63**

These results show that the BRTS has proved to be an environment friendly strategy to overcome the transportation needs of the urban commuters. It has reduced the VOC, CO, NO_X, and CO_2 emissions by 123.84 Tons/year, 1275.30 Tons/year, 92.88 Tons/year, and 27369 Tons/year respectively.

4.5. ECONOMIC IMPACTS

Transportation interventions aim to provide relief in terms of reduced travel time, improved safety and security, smoother traffic flow, reliable, comfortable and environmentally compatible transportation system. Such interventions focus on the economy and well-being of the general public as well. Once there is a transportation intervention, these interventions also have different impacts on the traffic, safety, social well-being, environment and economy. The traffic, safety and environmental impacts have been discussed in above paragraphs, the economic impacts of the transportation intervention i.e. implementation of Bus Rapid transit System (BRTS) has been analyzed and discussed in this part of research work.

An economic analysis assesses the effect of any improvement work, any event or an intervention on the economy. Economic impact analysis generally reflects in terms of measuring the changes in the business revenues, individual incomes, business earnings and other monetary outcomes of any event, intervention or project. It typically estimates and measures the changes in an economic activity and generally considers competitive alternatives. The economic impacts may be positive (benefits) and negative (costs) impacts. This analysis encompasses the net outcome of different performance measures within an activity or a project. It also gives an effective demonstration and overview of the economic output and contributions of a business activity, organization or a region or else a country. The economic impacts of an activity or a project can be categorized into direct impacts, indirect impacts, induced impacts and catalytic impacts.

The economic impacts of transportation projects and transportation improvement works aim towards the provision of data for the analysis in monetary terms. This provides the net benefits gained or losses as a result of transportation projects or related intervention. Projects related to transportation have various impacts on economic development of a community; such as employment, productivity, business activities, investments, property value, revenue generation, movement of people and goods and social well-being of any community or neighborhood etc. Such projects bring improvement in overall accessibility and mobility of the people. This results in the reduction in the transportation costs. These costs may reflect in terms of reduction in travel time, minimized vehicle operating costs, smoother traffic operations, road pricing and car parking costs, improved safety and reduction in environmental pollutions.

A public transport is an effective and important mean of transport to move the people in masses from one place to another in an economical manner. The impacts of public transport include mobility, accessibility, land use development, generation of jobs, energy efficient, reduction in travel time, better environmental quality and economic growth. All these factors are important while considering the economic aspects of public transportation services.

As discussed earlier, a Bus Rapid Transit System (BRTS) is a modern, effective and improved form of public transportation system; so just like the transportation, safety and environmental impacts assessment and evaluation, the economic impacts of the BRTS are also necessary to be evaluated. As argued in the above discussed transportation, safety and environmental impact evaluations that the BRTS is a new concept in Pakistan which is gaining rapid popularity in the country and different cities have opted to implement such projects. All these factors make it important to carry out an evaluation process to assess and evaluate such projects on the basis of certain performance indicators which include transportation, safety, environmental and economic impacts. Since this study aims at the evaluation of Bus Rapid Transit System (BRTS) of

Rawalpindi-Islamabad, the transportation, safety and environmental impacts have been analyzed assessed and results have been extracted from them. This part of the research work provides the economic impact evaluation of BRTS Rawalpindi-Islamabad.

Economic impact analysis uses the monetized savings of travel time analysis, savings of vehicle operating cost (VOC) analysis and savings of safety impact analysis. For the economic analysis, these three performance indicators were used because these were brought to monetary terms. These saving comes under the category of projects benefits. Besides these monetary benefits gained from the travel time, safety and VOC analysis, the revenue generated from the tickets sold to commuters of BRTS are also included as benefits which are already available in the monetary numbers. There are benefits of other parameters and sub-parameters as well which were not incorporated into economic analysis because those were not been monetized. These have been presented in the below table 4.23.

Table 4.23: Net Annual Saving

Performance indicator	**Net Annual Saving (Rs. Million)**
Travel Time Savings	395.07
VOC Savings	2,298.31
Safety Savings	234.25
Revenue Generated from Tickets Sold	796.69
Total	**3724.32**

The costs which were incorporated in the economic analysis included initial capital cost and annual costs of operations, maintenance, salaries and all the expenses which may incur during a period of one year. The initial capital cost data was taken from Capital Development Authority (CDA) and NESPAK (NESPAK, 2015)while other annual data of overall expenses was taken from Punjab Metrobus Authority (PMBA). The details of these cost data can be found as the

Appendix-E. These expenses have been categorized as costs in the economic impacts analysis. The detail of these data has been shown in the below table 4.24.

Table 4.24: Net Annual Costs

Expense/Cost	**Amount (Rs. Million)**
Initial Capital Cost	44,960.00
Annual O&M Costs	2,300.00

For analysis and evaluation of economic impacts, The Net Present Value (NPV) method has been used where all the costs and benefits are brought to a present value. NPV is the difference of present worth of benefits to that of the present worth of costs or expenses. This method presents the project value at the base year of analysis and can be found a suitable option in the decision making process. NPV is considered to be a suitable method of economic impact analysis because it provides the magnitude of net outcomes (benefits or costs) in the monetary terms. Among different alternative options of projects or policies, the alternative which has the highest net present value, is the most economical option. Mathematically, it can be written as

$$NPV = PW\ of\ Benefits - PW\ of\ Costs$$

Primarily the data required for the analysis and calculation of present worth includes the initial capital cost, annual benefits, annual costs, salvage value, interest rate and analysis period. Initial capital cost, annual benefits and annual cost data are available.

The analysis period was set to be as 20 years. This was done as from the literature, it was found that for the economic analysis of Monorail Public Transport Project in the Seattle downtown, the analysis period was set to be as 20 years starting from 2003(Consulting, &, & ECONorthwest, 2002). Another economic study of public transport of Helsinki city of Finland, the analysis period was set as 15 years. The economic analysis of "Commercial-Vehicle Information System & Networks Program" by FHWA, the analysis period they set was 25 years from 2000 to 2025 (Brand et al., 2002).

The salvage value is also an important element to be considered in economic analysis. This is an asset's estimated value in the situations where this asset has a value in the market if it is sold at that time. This value may be used to represent the worth of that asset at the end of analysis period. For the determination of salvage value Remaining Service Life (RSL) approach was adopted. RSL is the life of an asset which is remaining when the analysis period ends. In this approach, the overall cost of a particular component of an asset is divided over the entire service life of the component and then the remaining service life cost is subtracted from the entire service life cost. The four main components that may have a worth at the end of analysis period have been incorporated in the determination of salvage value. These components include pavement structure, grade separated fly overs, buses and platforms. From literature, the entire service life of pavement structure, grade separated fly overs, buses and platforms came out to be 35 years, 50 years, 20 years and 35 years respectively (Laver, Schneck, Skorupski, Brady, & Cham, 2007). So, the below table 4.25 presents the salvage value for the Life Cycle Cost Analysis (LCCA) based on RSL approach.

Table 4.25: Salvage value

Item	Cost (Millions)	Service life	Remaining service life	Salvage value (Millions)
Pavement structure	15,290.00	35	15	6,552.86
Fly overs	15,480.00	50	30	9,288.00
Buses	2,040.00	20	00	0.00
			Total	**15,840.86**

So, this salvage has been incorporated in life cycle cost analysis.

Another value that needs to be incorporated in the economic analysis is the interest rate. According to Sinha & Labi (2011), “The amount by which a given sum of money differs from its future value is typically represented as interest”. And the rate at which this interest adds up to its original value is called as the interest rate. This shows that the amount of money which a worth today will not be having the same worth in future. The interest amount adds to this amount of money and will increase its worth. The interest rate is typically charged on annual, bi-annual or quarterly basis. The interest may be referred as the price charged for borrowing money or “the time value of money”. For the analysis purpose and the current value of interest to be incorporated in the economic impact analysis, it was taken from the website of State Bank of Pakistan (SBP), which is 5.75% (SBP, 2017). This has been shown in the below figure 4.26. For simplicity in the analysis, a percentage of 6% has been used because the interest values in the interest tables provided by Sinha & Labi (2011) give 5%, 6%, 7% and so on. (Table provided as Appendix-F)

Table 4.26: Pakistan's Interest rate

Pakistan Money	Last	Previous	Highest	Lowest	Unit
Interest Rate	5.75	5.75	19.50	5.75	percent
Interbank Rate	6.01	6.01	17.42	1.21	percent
Money Supply M0	4703817.40	4823754.99	4838708.00	1413617.11	PKR Million
Money Supply M1	11781984.00	11773198.00	11892171.00	3168848.00	PKR Million
Money Supply M2	14339768.00	14306199.00	14394605.00	4431502.00	PKR Million
Money Supply M3	17833607.42	17788426.03	17841640.00	5548454.00	PKR Million
Deposit Interest Rate	4.83	6.00	8.68	1.63	percent
Foreign Exchange Reserves	19763.20	20400.90	24025.80	1973.60	USD Million

SOURCE: TRADINGECONOMICS.COM | STATE BANK OF PAKISTAN

Once all the values to be used in the economic analysis have been determined, the next was to select a suitable method of economic analysis. There are different method to be incorporated such as Present worth of Costs (PWC), Equivalent Uniform Annual Returns (EUAR), Equivalent Uniform Annual Costs (EUAC), Internal Rate of Return (IRR), Net Present Value (NPV) and Benefit–Cost Ratio (BCR) etc. Among all these methods Net Present Value (NPV) method has been found suitable because this method gives magnitude of nets costs or benefits. Net present value is the difference of Present worth (PW) of benefits to that of Present worth (PW) of costs. This method gives the project value at the base analysis year. Higher the NP value, economically more suitable and efficient the project will be.

Below table 4.27 summarizes the annual benefits, costs and other important values that have been used in the analysis of economic viability of BRTS Rawalpindi-Islamabad.

Table 4.27: Economic analysis parameter and their values

PROJECT BENEFITS (Rs. Million)	
Travel Time Savings	395.07
VOC Savings	2,298.31
Safety Savings	234.25
Revenue Generated from Tickets Sold	796.69
Total	**3,724.32**
Salvage Value	15,840.86
PROJECT COSTS (Rs. Million)	
Initial Capital Cost	44,960.00
Annual O&M Costs	2,300.00
OTHER IMPORTANT PARAMETERS/ VALUES	
Analysis Period	20 Years
Interest Rate	6.0 %

For easy understanding, below figure 4.8 shows the Cash Flow (CF) diagram of all the benefits and Costs being used in the economic analysis.

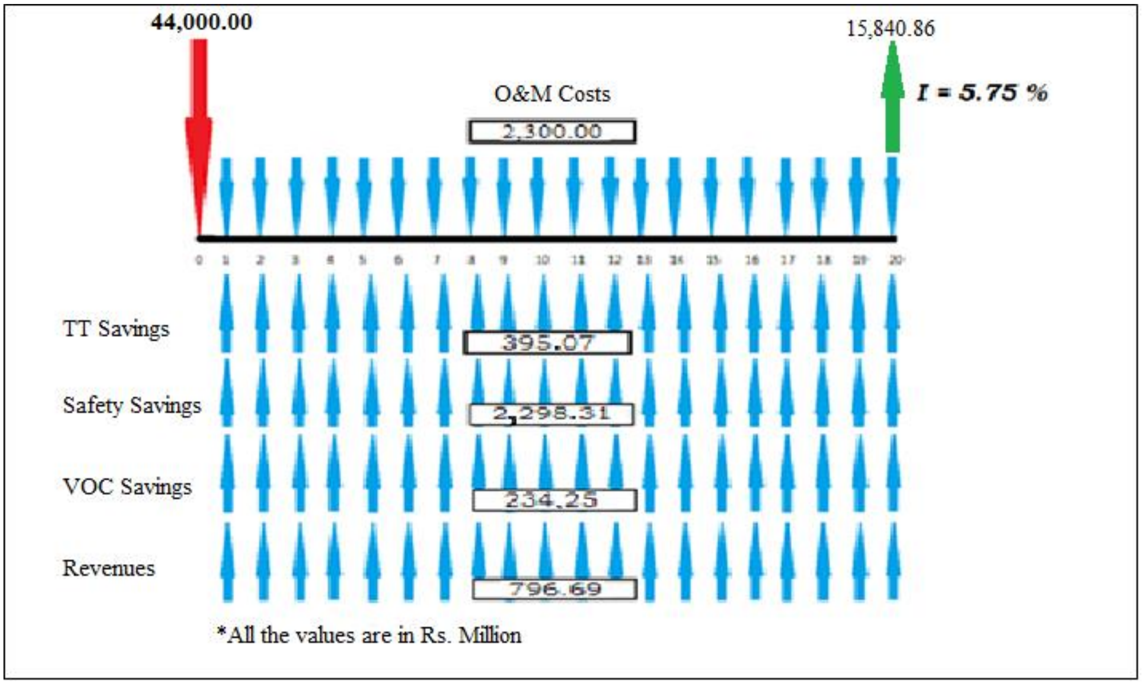

Figure 4.8: Economic analysis parameters and Values

After determining all the input values for the life cycle cost analysis (economic analysis), the net present value (NPV) general equation is as given below;

$$NPV = PW\ (Benefits) - PW\ (Costs) \qquad (4.1)$$

So, at first the PW of benefits has to be find out using the figure 4.8.

$$PW\ (Benefits) = 395.07USPWF\ (6\%, 20) + 2298.31USPWF\ (6\%, 20) + 234.25USPWF\ (6\%, 20) + 796.69USPWF\ (6\%, 20) + 15840.86SPPWF\ (6\%, 20)$$

Using the economic efficiency tables (Appendix-F) given by (Sinha & Labi, 2011), the above equation has been solved as;

$$PW\ (Benefits) = 4531.45 + 26361.62 + 2686.85 + 9138.03 + 4939.18$$

$$PW\ (Benefits) = 47657.13 \qquad (4.2)$$

Similarly, the PW (Costs) is calculated as;

$$PW\ (Costs) = 44000 + 2300USPWF\ (6\%, 20)$$

$$PW\ (Costs) = 44000.00 + 26381.00$$

$$PW\ (Costs) = 70381.00 \quad (4.3)$$

Now the net present value comes out by subtracting the PW (Costs) from PW (Benefits).i.e. subtracting equation (4.3) from equation (4.2). This gives;

$$NPV = PW\ (Benefits) - PW\ (Costs)$$

$$NPV = 47657.13 - 70381.00$$

$$\mathbf{NPV = -22723.87} \quad \mathbf{(4.4)}$$

Equation (4.4) gives net present value of the life cycle cost analysis. The negative value indicates that the project costs exceed the project benefits and the project is not economically viable. This is mainly because of the higher initial cost of BRTS construction.

Besides net present value method, Benefit to Cost Ratio (BCR) method has also been used to analyze the economic analysis of BRTS Rawalpindi-Islamabad. It is the ratio of project benefits to that of project costs. Project benefits and costs has already been calculated for the NPV analysis, so the BCR can be calculated as below;

$$\text{BCR} = \frac{\text{PW (Benefits)}}{\text{PW (Costs)}}$$

As the PW (Benefits) and PW (Costs) have already been calculated, so the above equation becomes;

$$\text{BCR} = \frac{47657.13}{70381.00}$$

$$\mathbf{BCR = 0.6771}$$

Also, the BCR indicates that the project costs exceed the project benefits by 32.29 %. BCR method also shows that the project is not economically suitable.

Despite of the savings by travel time, VOC, safety and the revenue generation, the project is not being economically suitable. A closer analysis indicates that the main reason which is making the BRTS project uneconomical is the initial cost of BRTS construction.

Similar kind of NPV and BCR analysis has been carried out to know the viability of BRTS project on annual basis by not considering the initial cost of BRTS construction and the salvage value. The NPV method of economic analysis is as follows:

$$\text{NPV} = \text{PW (Benefits)} - \text{PW (Costs)} \qquad (4.5)$$

So, at first the PW of benefits has to be find out.

$$\text{PW (Benefits)} = 395.07\text{USPWF} (6\%, 20) + 2298.31\text{USPWF} (6\%, 20) + 234.25\text{USPWF} (6\%, 20) + 796.69\text{USPWF} (6\%, 20)$$

Using the economic efficiency tables (Appendix-F) given by (Sinha & Labi, 2011), the above equation has been solved as;

$$\text{PW (Benefits)} = 4531.45 + 26361.62 + 2686.85 + 9138.03$$

$$\text{PW (Benefits)} = 42717.95 \qquad (4.6)$$

Similarly, the PW (Costs) is calculated as;

$$\text{PW (Costs)} = 2300\text{USPWF} (6\%, 20)$$

$$\text{PW (Costs)} = 26381.00 \qquad (4.7)$$

Now the net present value comes out by subtracting the PW (Costs) from PW (Benefits).i.e. subtracting equation (4.7) from equation (4.6). This gives;

$$\text{NPV} = \text{PW (Benefits)} - \text{PW (Costs)}$$

$$\text{NPV} = 42717.95 - 26381.00$$

$$\mathbf{NPV = 16336.95} \qquad \mathbf{(4.8)}$$

The above equation (4.8) shows that the project is economically suitable, if the annual costs and benefits are considered. This analysis does not consider the initial capital cost and the salvage value.

Similarly, the BCR analysis has also been carried out. Using the results of the above equations, the BCR analysis is as follows:

$$\text{BCR} = \frac{\text{PW (Benefits)}}{\text{PW (Costs)}}$$

As the PW (Benefits) and PW (Costs) have already been calculated, so the above equation becomes;

$$\text{BCR} = \frac{42717.95}{26381.00}$$

$$\mathbf{BCR = 1.619}$$

Above BCR value indicates that the project benefits increase the project costs and the project is economically viable on the basis of analysis of annual project benefits and costs.

From the above analysis, it can be inferred that the initial project construction cost is very high since it was a big project. So two different analyses were carried out; first one was to include all the benefits and costs which included initial capital cost, annual O&M costs, annual benefits (savings) and the salvage value. The results of this analysis revealed that the projects costs exceed the project benefits. This is because of the fact that the initial construction cost of project was very high. So, the economic analysis showed that the project is economically not suitable. Here, one point to be discussed is that the only three performance parameters (i.e. travel time, VOC and safety savings) were brought into monetary terms and the economic analysis was carried out using the monetary benefits of these three parameters only. There are other benefits of BRTS project which were analyzed but not monetized such as reduction in vehicular emissions (environmental impact analysis). System reliability, comfort, convenience and positive user perception are other benefits which have not been analyzed and monetized in this research study. If these benefits were analyzed and monetized, the results of economic analysis might be different and the project might be economically suitable.

Due to these reasons, economic analysis of only the annual cost and benefits of the project was carried out. The results of economic analysis of NPV showed a positive value indicating the project to be economically viable. Also the BCR came up with the greater than one, which also is an indication of suitability of project on the basis of economic analysis. The following table 4.28 summarizes the results of economic analysis.

Table 4.28: Economic Analysis Results with & without Initial Capital Cost & Salvage Value

Economic Analysis With Initial Capital Cost & Salvage Value		
Analysis Type	**Result**	**Remarks**
Net Present Value (NPV)	- 22,723.87	Economically Not Viable
Benefit to Cost Ratio (BCR)	0.6771	Economically Not Viable
Economic Analysis Without Initial Capital Cost & Salvage Value		
Analysis Type	**Result**	**Remarks**
Net Present Value (NPV)	16,336.95	Economically Viable
Benefit to Cost Ratio (BCR)	1.619	Economically Viable

CHAPTER 5

5. CONCLUSION AND RECOMMENDATIONS

5.1. SYNOPSES OF RESEARCH

Increasing travel demand has become a major concern for the developing nations. To cope with such problems, a remedial measure of introduction of improved and sustainable public transportation system has been adopted. Public transport is a mean by which many people in one time move to different places sharing the same common passenger transit service. These services include wagons, buses, trams, rapid transit buses and rails, ferries etc. Public transport is relatively an economical option for the people to opt. In a developing country like Pakistan, people mainly rely on public transport for their daily transportation needs. That’s why Government has initiated different public transit services. So, the Monitoring and Evaluation of such public projects is mandatory to assess and examine the current project and at the same time helps in decision making regarding the implementation of such projects. This research study was aimed to carry out an evaluation process to know transportation, safety, environment and economic impacts of BRTS Rawalpindi-Islamabad. Different sub-parameters under the main parameter of transportation, safety, environment and economic impacts were analyzed and evaluated, and the results were extracted from these analysis. Analysis revealed that BRTS has helped in improvement of public transportation system of Rawalpindi and Islamabad. Travel time of BRTS commuters has reduced, their safety has improved, travel through BRTS has become economical, Level of Service (LOS) on the roads has improved and environment has been benefited.

5.2. RESEARCH FINDINGS AND CONCLUSIONS

The finding and conclusions from the research work has been discussed under following headings.

5.2.1. Findings and Conclusions from Literature Review

These include:

1. Different developed countries have carried out the assessment, evaluation and monitoring of their public transportation systems on the basis of certain performance parameters and some have compared different alternative public transportation services.
2. A very little work has been carried out on the evaluation and monitoring of public transportation services in the developing or less developed countries.
3. At national level, no work has been conducted on the assessment, evaluation and monitoring of public transportation system especially Bus Rapid Transit System (BRTS), which has emerged as a rapid growing public transportation system in the country.
4. From the literature it has been extracted that the public transportation services like BRTS, LRTS or MRTS provide better transportation services, reduced travel times, economical, comfortable, reliable and safer voyages and have been proven to be environmentally compatible services for the people to move within the city.
5. Such transportation services have also an effect on land uses and surrounding property. From the literature, it has been found that the property located closer to such services have a higher value than the property located farer from the BRTS or other such transportation services.
6. Some negative impacts or the disadvantages of BRTS include higher initial construction costs, higher unit operating cost, social dis-integration and air and noise pollution during the construction period etc.

5.2.2. Findings and Conclusions from Transportation Impact Analysis

Transportation impact was one of the most important and detailed discussed parameter of the research study. It included several sub-parameters in it. The key findings and conclusions extracted from the analysis of transportation impacts and its sub-parameters include:

1. BRTS has proved to be a good intervention in reducing the travel time of the commuters using the BRTS, who previously were using different modes of transportation. Based on

the results of the data analyzed, annually an average of 734 minutes of each of the commuter has been saved who has switched to BRTS.

2. This reduction in travel time when monetized, corresponded to an amount of 395.07 million rupees per year. This also validates the claim that BRTS is an economical option of public transport for the people to choose.
3. Bus Rapid Transit System has found to be a good intervention to help reduce these costs by reducing the number of vehicles on the roads. Once the number of vehicles get reduced, the LOS of service on the roads gets improved, which ultimately minimizes the vehicle operating cost (VOC). In terms of VOC savings, an amount of 2,298.31 Million rupees annually has been saved by the initiation of operations of BRTS.
4. BRTS has shown to be a strategy to mitigate the traffic congestion. After the BRTS operations, the Level of Service (LOS) on Murree road has been improved from LOS-F to LOS-E and LOS-D to LOS-C in direction-1 and direction-2 respectively. The vehicular density on Murree road has also been improved.
5. BRTS has helped in reducing the number of vehicles on the roads. A number of people who were previously using other modes of transportation have been shifted to BRTS after the start of its operations.
6. Analysis of the modal shift suggests that 57.66% of BRTS commuters have been shifted from public transport. Also a percentage of 18.70%, 10.91%, 9.87% and 2.86% of the BRTS commuters have been shifted from motor bikes, taxis, private vehicles and rickshaws respectively. From these results it can be concluded that ordinary public transportation services in the twin cities have a very poor performance since more than 50% of the BRTS commuters have switched from public transport.
7. Research study and the survey from the general public revealed that the current public transport within the twin cities operates at a very poor service quality.
8. The average ridership demand for the BRTS Rawalpindi-Islamabad was initially calculated by NESPAK as 1,35,000 passengers per day. But this ridership demand is not being achieved and currently an average ridership of 1,10,000 passengers per day is being experienced.

9. From the literature, it was found that globally, most of the public transport services such BRTS are subsidized because these are better services provided by the government to the general public. Hence, a lower fare is appreciated for such projects.
10. Ridership demand analysis reveals that increasing the fare reduces the ridership demand and hence, the net revenue decreases.
11. From the analysis of the current BRTS fare, it was concluded that the current BRTS fare i.e. Rs. 20 is of a lesser amount and the highest revenue can be generated when the fare is increased to Rs.25. Even if the fare is increased to Rs.30, still it gives more revenue than that of the current fare level. Increasing the fare from Rs.30, results in a major drop in the ridership and ultimately, a lower revenue generation.
12. Optimum fare analysis suggests that current fare is of a lesser amount and the optimum fare was found to be set as Rs.25.
13. From the analysis of Price Elasticity of Demand (PED), it was found that the demand is inelastic when the fare is Rs. 20. And then as the fare increases the elasticity also gets increased. It further describes that as the fare approaches Rs. 25, this increase in price produces a small reduction in demand, since its PED value is nearer to unit elasticity i.e. 1.12. The value of elasticity is highest i.e. 2.84, when the fare is Rs. 35. This can be interpreted as if the fare is increased up to Rs.35, the ridership will decrease considerably.
14. The PED analysis further suggests that the current fare lies at a PED value of 0.18, where the demand is inelastic. Hence, this is not a reasonable fare level. So, an increase in fare level up to Rs. 25 is recommended.
15. The capacity analysis of the BRTS Rawalpindi-Islamabad indicates that the system is operating at a lower capacity level. The overall system operates at a volume to capacity ratio (V/C) of 0.5786. This implies that the occupancy of BRTS buses is 57.86%.
16. Furthermore, from these results the peak hour was found to be the time between 5:00 PM to 6:00 PM where the V/C ratio is approaching 1.0 i.e. 0.937 or 93.7%.

5.2.3. Findings and Conclusions from Safety Impact Analysis

Safety analysis was also an important parameter to evaluate the BRTS Rawalpindi-Islamabad. Road safety is getting rapid popularity among transportation officials. The key findings and the conclusions taken out from the safety impact analysis include:

1. Analysis of safety impacts of BRTS indicates that the BRT service has proven to be an improvement in the field of traffic safety. A considerable number of fatal and non-fatal crashes have been saved due to the start of the operations of BRTS Rawalpindi-Islamabad.
2. Safety impact analysis further conclude that when monetizing the fatal and non-fatal crashes, an amount of Rs. 9.64 million and Rs. 224.61 million have been saved annually from the reduction in fatal and non-fatal crashes respectively. This corresponds to a total saving of Rs. 234.25 million per year.

5.2.4. Findings and Conclusions from Environmental Impact Analysis

Another import parameter that was used in the evaluation framework of BRTS Rawalpindi-Islamabad was to analyze the impact of the project on the environment. Before and after the implementation of BRTS scenarios were analyzed to assess the viability and applicability of the service. Different environmentally hazardous emissions were calculated for pre and post scenarios. The important findings and conclusions from the analysis of environmental impacts include:

1. From the environmental impact analysis, it was found that the BRTS Rawalpindi-Islamabad has helped in reducing the environmentally hazardous gases produced by transportation vehicles as the number of vehicles have been reduced after the BRTS operations.
2. After the start of BRTS operations, the analysis results show that there has been a reduction in the emissions of VOC, CO, NO_X, and CO_2 by 123.84 Tons/year, 1275.30 Tons/year, 92.88 Tons/year, and 27369 Tons/year respectively.

5.2.5. Findings and Conclusions from Economic Impact Analysis

Economic impact analysis was one of the important performance indicators incorporated into the BRTS evaluation. The key findings of this analysis include:

1. The economic analysis included the assessment into two scenarios. First one was to analyze incorporating all the monetized benefits and costs (Capital cost, annual costs & benefits and the salvage value) while the second one included only the annual benefitsand costs.
2. The analysis was carried out into two scenarios because in the first scenario, incorporating all the benefits and costs gave the negative NPV. Since there are other parameters such as environmental impacts, social impacts, system sustainability and system comfort and convenience were not monetized, so these results were assumed to be not realistic. That's why another scenario was also used to assess the economic impacts based on annual benefits and costs.
3. The results of the analysis of first scenario gave a negative NPV and BCR value less than one, which indicates that the project costs exceed the project benefits and so the project is not economically viable.
4. The results of the analysis of second scenario gave a positive NPV and BCR value greater than one, which indicates that the project benefits exceed the project costs and so the project is economically viable.
5. These NPV values for first and the second scenario are – 22,723.87 and 16,336.95 respectively.
6. Similarly, the BCR values for first and the second scenario came out to be0.6771 and 1.619 respectively.

5.3. RECOMMENDATIONS

Post implementation evaluation of a project especially a sort of public transportation project has not been done in Pakistan. So this research work is a unique one in its kind. At the same time, Bus Rapid Transit System (BRTS) is also a new concept in the country and gaining rapid popularity as well. In couple of cities, its operations have been started and few other cities are planning to have such services. Since, it's a new concept in the country, so a number of improvements need to be done. This research study highlighted several improvements that need to be done for a better and improved public transportation service. Recommendations and the future work need to be done are listed below.

1. Bus Rapid Transit System (BRTS) is getting rapid popularity in the country. So, there is a great need to evaluate, assess and monitor such projects to check the viability as well as bring improvements in the system.
2. Feeder routes need to be incorporated in the system, so that the people from outlying areas may be benefited from this service.
3. Feeder routes would help in increasing the ridership of BRT service which ultimately would increase the revenue generation.
4. Current BRTS fare is not an optimum one. So an optimum fare, as determined may be set to a fare level between Rs. 25 to Rs.30.
5. BRTS operates in both Islamabad and Rawalpindi city, the Rawalpindi part of the BRTS experiences a very higher ridership during certain hours of the day. So, it is recommended to use higher number of buses in Rawalpindi part in the hours where system encounters with an increased ridership.
6. During off peak hours of the day where V/C ratio is very low, a reduced number of buses may be used to minimize the transportation costs.
7. The current research study focused on assessment and the evaluation of transportation, safety, environmental and economic impacts. There are some other important parameter where BRTS need to be assessed which mainly include social impact analysis and system sustainability.
8. Research study and the survey from the general public revealed that the current public transport within the twin cities operates at a very poor service quality. So, it is recommended that the Government should improve the quality of public transport especially in the areas where BRTS does not operate.
9. To increase the revenue generation, advertisements may be done at BRTS stations, along the BRTS routes and in and on the buses. This will also help in minimizing the subsidy being provided by the Government.

5.4. RECOMMENDATIONS FOR FUTURE WORK

Keeping in view the scope of work, current study focused on certain parameters related to BRTS evaluation. There are other parameters on the basis of which, the BRT system may also be evaluated. So, the recommendations for the future work may be carried out are as follows:

1. The current research study focused on assessment and the evaluation of transportation, safety, environmental and economic impacts. There are some other important parameters where BRTS need to be assessed which mainly include social impact analysis and system sustainability.
2. Research work may also be carried out to evaluate the user perception regarding the BRT service.

5.5. CONTRIBUTIONS THROUGH THIS RESEARCH

The contributions through this research work are listed below:

1. Bus Rapid Transit System is a new concept in the country. No work has been carried out to assess the viability and other technical aspects of the system. So this work is a first of this kind of effort which may help the decision makers regarding the implementation of such projects in other cities of the country.
2. This research study may help the operating agencies to bring improvements in the system.
3. This research study may also provide the basis for the evaluation of other assessment parameters such as social impacts, user perception and system sustainability and system comfort and convenience.

LIST OF REFERENCES

Anderson, M. L. (2014). Subways, strikes, and slowdowns: The impacts of public transit on traffic congestion. *The American Economic Review, 104*(9), 2763-2796.

Anderson, P. L., McLellan, R. D., Overton, J. P., & Wolfram, G. L. (1997). Price elasticity of demand. *McKinac Center for Public Policy. Accessed October, 13*, 2010.

Brand, D., Parody, T., Orban, J., & Brown, V. (2002). Benefit-cost analysis of the Commercial Vehicle Information Systems and Networks program. *Transportation Research Record: Journal of the Transportation Research Board*(1800), 35-43.

Brand, D., T. E. Parody, J. E. Orban, and V. J. Brown. "Benefit-Cost Analysis of the Commercial Vehicle Information Systems and Networks Program." *Transportation Research Record: Journal of the Transportation Research Board, No. 1800*, TRB, National Research Council, Washington, D.C., 2002. pp. 58-66.

Booz-Allen & Hamilton Inc. (1999), *California Life-Cycle Benefit/Cost Analysis Model (Cal-B/C)—Technical Supplement to User's Guide*, California Department of Transportation;

Cain, A., Flynn, J., McCourt, M., & Reyes, T. (2009). Quantifying the importance of image and perception to Bus Rapid Transit.

Cambridge Systematics (1998), *Economic Impact Analysis of Transit Investments: Guidebook for Practioners*, Report 35, TCRP, Transportation Research Board

Carpenter, T. G. (1994). The Environmental Impact of Railways, Wiley, Chichester, UK.

Center, M. (1998). Highway Capacity Software-3. *University of Florida, Gainesville, FL*.

Charles, P. (2017). What is transport demand? - Transport Futures Institute -. Transport Futures Institute. Retrieved 9 June 2017, from http://www.transport-futures.com/transport-demand/

Cham, L., Chang, M., Chung, J., Darido, G., Geilfuss, C., Henry, D., . . . Schneck, D. (2006). Honolulu Bus Rapid Transit (BRT) Project Evaluation.

Chiu Chuen, O., Karim, M. R., & Yusoff, S. (2014). Mode choice between private and public transport in Klang Valley, Malaysia. *The Scientific World Journal, 2014*.

Consulting, D., &, & ECONorthwest. (2002). Benefit-Cost Analysis of the

Proposed Monorail Green Line. *P`repare for Elevated Transportation Company, Seattle, Washington*.

Cournot, A. A. (1843). *Exposition de la théorie des chances et des probabilités*: L. Hachette.

Cournot, A. A. 1838. "Brief on the applications of calculation of chances to the statistics judicial." *Journal of pure and applied mathematics.*12. T. 3

Daganzo, C. F., Laval, J., & Muñoz, J. C. (2002). Ten strategies for freeway congestion mitigation with advanced technologies. *California Partners for Advanced Transit and Highways (PATH).*

Dargay, J., Gately, D. (1997). Demand for transportation fuels: imperfect price reversibility? Transp. Res. B, Vol. 31, No. 1, pp. 71–82.

Definition of 'Law Of Demand' - The Economic Times. (2017). *The Economic Times*. Retrieved 12 June 2017, from http://economictimes.indiatimes.com/definition/law-of-demand

Dahdah, S., & McMahon, K. (2008). The true cost of road crashes: valuing life and the cost of a serious injury. *International Road Assessment Programme, World Bank Global Road Safety Facility*.

Daniel J. Graham (2007), *Agglomeration Economies and Transport Investment*, Discussion Paper No. 2007-11, Joint Transport Research Centre, OECD and International Transport Forum, at http://puck.sourceoecd.org/vl=9745622/cl=32/nw=1/rpsv/cgibin/wppdf?file=5kzbxsv5nnjk.pdf.

David J. Forkenbrock and Glen E. Weisbrod (2001), *Guidebook for Assessing the Social and Economic Effects of Transportation Projects*, NCHRP Report 456, Transportation Research Board, National Academy Press

Davison, L. J., & Knowles, R. D. (2006). Bus quality partnerships, modal shift and traffic decongestion. *Journal of Transport Geography, 14*(3), 177-194.

Delbosc, A., & Currie, G. (2012). Modelling the causes and impacts of personal safety perceptions on public transport ridership. *Transport Policy, 24*, 302-309.

Deng, T., & Nelson, J. D. (2012). The perception of bus rapid transit: A passenger survey from Beijing Southern Axis BRT Line 1. *Transportation Planning and Technology, 35*(2), 201-219.

EDRG (2001), *Guide for Using Empirical Information to Measure Economic Impact of Highway Investments*, Federal Highway Administration, Economic Development Research Group

Faiz, A., Weaver, C. S., & Walsh, M. P. (1996). *Air pollution from motor vehicles: standards and technologies for controlling emissions*: World Bank Publications.

Faiz, A., Weaver, C. S., Walsh, M. P. (1996b). Air Pollution from Motor Vehicles, World Bank, Washington, DC.

Flynn, J., Thole, C., Perk, V., Samus, J., & Van Nostrand, C. (2011). Metro Orange Line BRT Project Evaluation.

Fouquet, R. (2012). Trends in income and price elasticities of transport demand (1850–2010). *Energy Policy, 50*, 62-71.

Fuller, S. (2010). Life-cycle cost analysis (LCCA). *National Institute of Building Sciences, An Authoritative Source of Innovative Solutions for the Built Environment (www. WBDG. org, Washington).*

Gunn, H. F., & Sillaparcharn, P. (2007). An Introduction to the valuation of travel time-savings and losses *Handbook of Transport Modelling: 2nd Edition* (pp. 503-517): Emerald Group Publishing Limited.

Hamer, P. (2010). Analysing the effectiveness of park and ride as a generator of public transport mode shift. *Road & Transport Research: A Journal of Australian and New Zealand Research and Practice, 19*(1), 51.

Hidalgo, D., Pereira, L., Estupiñán, N., & Jiménez, P. L. (2013). TransMilenio BRT system in Bogota, high performance and positive impact–Main results of an ex-post evaluation. *Research in Transportation Economics*, *39*(1), 133-138.

Holmen, B. A., Niemeier, D. A. (2003). Air quality, in Handbook of Transport and the Environment, ed. Hensher, D. A., Button, K. J., Elsevier, Amsterdam, The Netherlands.

Hombarger, W. S., Hall, J. W., Reilly, W. R., Sullivan, E. C. (2001). Fundamentals of Traffic Engineering, 13th ed., Institute of Transportation Studies, University of California, Berkeley, CA.

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

Irfan, M. (2008). Pakistan's wage structure. *Pakistan Institute of Development Economics*, 1-47.

Jaiswal, S., Bunker, J., & Ferreira, L. (2010). Influence of platform walking on BRT station bus dwell time estimation: Australian analysis. *Journal of Transportation Engineering*, *136*(12), 1173-1179.

Jaiswal, S. K. (2010). *Busway platform bus capacity analysis.* Queensland University of Technology.

Jang, W. (2010). Travel time and transfer analysis using transit smart card data. *Transportation Research Record: Journal of the Transportation Research Board*(2144), 142-149.

Kim, E., Hewings, G. J., & Hong, C. (2004). An application of an integrated transport network–multiregional CGE model: a framework for the economic analysis of highway projects. *Economic Systems Research*, *16*(3), 235-258.

Krygsman, S., Dijst, M., & Arentze, T. (2004). Multimodal public transport: an analysis of travel time elements and the interconnectivity ratio. *Transport Policy*, *11*(3), 265-275.

Laver, R., Schneck, D., Skorupski, D., Brady, S., & Cham, L. (2007). Useful life of transit buses and vans.

Lehtonen, M., & Kulmala, R. (2002). Benefits of pilot implementation of public transport signal priorities and real-time passenger information. *Transportation Research Record: Journal of the Transportation Research Board*, (1799), 18-25.

Levinson, H., Zimmerman, S., Clinger, J., Rutherford, S., Smith, R. L., Cracknell, J., & Soberman, R. (2003). Bus rapid transit. *Transit Cooperative Research Program Report, 90*.

Levinson, H. S. (1983). *Analyzing transit travel time performance*.

Levy, J. I., Buonocore, J. J., & Von Stackelberg, K. (2010). Evaluation of the public health impacts of traffic congestion: a health risk assessment. *Environmental health*, *9*(1), 65.

Li, Z., & Madanu, S. (2009). Highway project level life-cycle benefit/cost analysis under certainty, risk, and uncertainty: methodology with case study. *Journal of Transportation Engineering, 135*(8), 516-526.

Litman, T. (2009). Transportation cost and benefit analysis. *Victoria Transport Policy Institute, 31*.

Litman, T. (2005). Transportation Elasticities: How Prices and Other Factors Affect Travel Behavior, Victoria Transport Policy Institute, Victoria, BC, Canada.

Litman, T. (2013a). Safer Than You Think!: Revising the Transit Safety Narrative.

Litman, T. (2013b). Understanding transport demands and elasticities. *How prices and other factors affect travel behavior.(Victoria Transport Policy Institute: Litman) Available at http://www. vtpi. org/elasticities. pdf [Verified 22 November 2013]*.

Mackie, P., Jara-Dıaz, S., & Fowkes, A. (2001). The value of travel time savings in evaluation. *Transportation Research Part E: Logistics and Transportation Review, 37*(2), 91-106.

Maitra, B., Sikdar, P., & Dhingra, S. (1999). Modeling congestion on urban roads and assessing level of service. *Journal of Transportation Engineering, 125*(6), 508-514.

Mane, A. S., Sarkar, A. K., & Arkatkar, S. S. (2015). *Study of Modal Shift to Bus Rapid Transit (BRT) in Developing Country: A Case Study in India.* Paper presented at the Transportation Research Board 94th Annual Meeting.

Mathew, T. V., & Rao, K. K. (2006). Introduction to Transportation engineering. *Civil Engineering–Transportation Engineering. IIT Bombay, NPTEL ONLINE, http://www. cdeep. iitb. ac. in/nptel/Civil% 20Engineering*.

McMahon, K., & Dahdah, S. (2008). The True Cost of Road Crashes, Valuing life and the cost of serious injury. *London: iRAP*.

MetroBus concerns (2014, May 15), *Dawn News*. Retrieved fromhttps://www.dawn.com/news/1106281

Nantulya VM, Muli-Musiime F. Kenya (2001). Uncovering the social determinants of road traffic accidents. In: Evans T, Whitehead M, Diderichsen F, Bhuiya A, Wirth M, editors. Challenging inequities: from ethics to action. Oxford: Oxford University Press;.

NESPAK. (2015). Transporting Modeling for Mass Transit System in Rawalpindi & Islamabad (Vol. 1).

Newnam, J. (2011). Environmental Benefits of Public Transportation.

Nurdden, A., Rahmat, R., & Ismail, A. (2007). Effect of transportation policies on modal shift from private car to public transport in Malaysia. *Journal of applied Sciences, 7*(7), 1013-1018.

Parry, I. W., & Small, K. A. (2009). Should Urban Transit Subsidies Be Reduced? *The American Economic Review*, 700-724.

Patankar, V. M., Kumar, R., & Tiwari, G. (2007). Impacts of bus rapid transit lanes on traffic and commuter mobility. *Journal of urban planning and development, 133*(2), 99-106.

Paulley, N., Richard Balcombe, Roger Mackett, Helena Titheridge, John Preston, Mark Wardman, Jeremy Shires, and Peter White. (2006). The demand for public transport: The effects of fares, quality of service, income and car ownership. *Transport Policy, , 13(4),,* 295-306.

Perić, T. (2001). Factors of Traffic Demand. *PROMET-Traffic&Transportation, 13*(4), 233-238.

R King, J. M. V., M. Raifman, Nicolae Duduta, Aileen Carrigan. (2014). Social, Environmental and Economic Impacts of BRT Systems. Bus Rapid Transit Case Studies from Around the World, from http://thecityfixbrasil.com/files/2013/12/EMB13_HSBC_BRTimpacts_Executive_Summary_26_Nov_2013.pdf&sa=U&ei=cHRTU9KdLaTG2wXT6YDgBw&ved=0CCAQFjAB&usg=AFQjCNHBMa98Kpz-x-MPk-qLw6zxzTDmNQ

Rahane, S. K., & Saharkar, U. (2014). Traffic congestion-causes and solutions: a study of talegaon Dabhade city. *J. Inf. Knowl. Res. Civil Eng, 3*(1), 160-163.

Redman, L., Friman, M., Gärling, T., & Hartig, T. (2013). Quality attributes of public transport that attract car users: A research review. *Transport Policy, 25*, 119-127.

Reilly, J., & Levinson, H. (2011). Public Transport Capacity Analysis Procedures for Developing Cities.

Rietveld, P. (2001). Environmental effects of public transport: on the gap between average and marginal costs: Tinbergen Institute Discussion Paper.

Roess, R. P., Prassas, E. S., & McShane, W. R. (2011). Traffic engineering.

Sactra (1999), *A Framework for Assessing Studies of the Impact of Transport Infrastructure Projects on Economic Activity*, Standing Advisory Committee on Trunk Road Assessment, Dept. of Environment, Transport and Regions

Sahoo, P., Rao, S., & Kumar, V. (1996). A study of traffic flow characteristics on two stretches of national highway no. 5. *Indian highways*.

SBP. (2017). Structure of Intereset rates, State Bank of Pakistan. *Economic Data* Retrieved 20 November, 2017, from http://www.sbp.org.pk/ecodata/index2.asp

Sinha, K. C., & Labi, S. (2011). *Transportation decision making: Principles of project evaluation and programming*: John Wiley & Sons.

Solomon, M. M., Baker, E. K., & Schaffer, J. R. (1988). vehicle routing and scheduling problems with time window constraints: efficient implementations of solution improvement procedures. vehicle routing: methods and studies. studies in management science and systems-volume 16.

Statistical Annex. Retrieved 12 September 2017, from http://www.who.int/violence_injury_prevention/publications/road_traffic/world_report/statistical_annex.pdf

Teunissen, T. (2014). *An ex-post evaluation framework for BRT and MRT in Mexico: A study on the impacts of Bus Rapid Transit and Mass Rapid Transit in Mexico City*. University of Twente.

USEPA, U. (1992). Environmental Protection Agency (2004). *A Consolidated Emissions Modeling System for mobile6 and nonroad, US Environmental Protection Agency, Office of Transportation and Air Quality, National Mobile Inventory Model (NMIM)*.

USEPA (1997). Emission Factors for Locomotives: Technical Highlights, EPA 420-F-97-051, Air and Radiation, Office of Mobile Sources, U.S. Environmental Protection Agency, Washington, DC.

Wang, Y., Wang, Z., Li, Z., Staley, S. R., Moore, A. T., & Gao, Y. (2012). Study of modal shifts to bus rapid transit in Chinese cities. *Journal of Transportation Engineering, 139*(5), 515-523.

Watkins, L. H. (1981). Environmental impact of roads and traffic (No. Monograph).

Wardman, M. (1997). Inter-urban rail demand, elasticities and competition in Great Britain: Evidence from direct demand models. *Transportation Research Part E: Logistics and Transportation Review, 33*(1), 15-28.

Weisbrod, G., & Reno, A. (2009). *Economic impact of public transportation investment*. American Public Transportation Association.

Widana Pathiranage, R., Bunker, J. M., & Bhaskar, A. (2013). A microscopic simulation model to estimate bus rapid transit station service capacity with mixed stopping and non-stopping bus operation.

WHO Mortality Database. WHO Mortality Statistics. Geneva, World Health Organization, 2002.

World Health Organization. Violence, Injury Prevention, & World Health Organization. (2013). Global status report on road safety 2013: supporting a decade of action. World Health Organization.

APPENDICES

APPENDIX-A: Travel Time Calculations Using Data of the Survey From BRTS Commuters.

APPENDIX A-01: Public Transport TT Calculation

Sr. No:	Survey form No:	Current TT (Minutes)				Previous TT (Minutes)	TT saving (Minutes)
		Home/w.place to BRT stn	Stn to stn time	BRT stn to home/W.Place	Total TT		
1	1	5	22.89	10	37.89	40	**2.11**
2	2	8	29.19	20	57.19	70	**12.81**
3	5	10	6.87	10	26.87	40	**13.13**
4	6	6	15.14	6	27.14	38	**10.86**
5	8	10	24.82	10	44.82	45	**0.18**
6	9	20	26.74	25	71.74	80	**8.26**
7	10	20	14.5	45	79.5	90	**10.5**
8	12	8	41.77	8	57.77	68	**10.23**
9	14	10	33.97	8	51.97	90	**38.03**
10	15	10	12	32.09	54.09	45	**-9.09**
11	18	15	18.8	10	43.8	45	**1.2**
12	19	10	33.21	10	53.21	90	**36.79**
13	21	10	15.69	5	30.69	37	**6.31**
14	22	8	11.1	5	24.1	30	**5.9**
15	24	10	16.95	10	36.95	50	**13.05**
16	26	10	15.38	8	33.38	40	**6.62**
17	27	8	4.3	8	20.3	25	**4.7**
18	29	5	15.69	5	25.69	60	**34.31**
19	32	10	23.32	30	63.32	60	**-3.32**
20	33	5	11.35	15	31.35	45	**13.65**
21	36	22	43.69	45	110.69	130	**19.31**

22	38	10	30.19	15	55.19	60	**4.81**
23	41	12	23.32	35	70.32	83	**12.68**
24	42	5	30.19	5	40.19	80	**39.81**
25	44	20	29.23	5	54.23	60	**5.77**
26	46	8	38.95	15	61.95	95	**33.05**
27	47	8	6	8	22	25	**3**
28	48	5	8.92	10	23.92	35	**11.08**
29	49	5	25.67	60	90.67	90	**-0.67**
30	50	5	43.69	5	53.69	60	**6.31**
31	52	10	19.17	10	39.17	45	**5.83**
32	53	8	34.6	10	52.6	60	**7.4**
33	55	8	16.1	8	32.1	45	**12.9**
34	57	8	15.4	10	33.4	40	**6.6**
35	58	8	13.79	7	28.79	37	**8.21**
36	62	10	30.35	15	55.35	75	**19.65**
37	64	7	14.17	8	29.17	35	**5.83**
38	65	10	11.55	5	26.55	25	**-1.55**
39	70	10	34.6	7	51.6	70	**18.4**
40	71	8	32.23	13	53.23	75	**21.77**
41	73	8	13.5	7	28.5	30	**1.5**
42	75	10	45.95	13	68.95	90	**21.05**
43	77	8	22.89	7	37.89	45	**7.11**
44	80	8	14.02	8	30.02	30	**-0.02**
45	83	8	41.95	12	61.95	90	**28.05**
46	84	8	13.48	8	29.48	30	**0.52**
47	85	5	19.27	10	34.27	45	**10.73**
48	90	8	44.02	10	62.02	90	**27.98**
49	91	6	30.19	10	46.19	65	**18.81**
50	93	6	35.23	8	49.23	70	**20.77**

51	94	8	31.6	6	45.6	67	**21.4**
52	98	10	34.6	8	52.6	70	**17.4**
53	100	10	36.27	5	51.27	75	**23.73**
54	101	12	21	9	42	60	**18**
55	102	6	17.02	8	31.02	40	**8.98**
56	105	15	25.34	7	47.34	65	**17.66**
57	107	8	17.06	7	32.06	38	**5.94**
58	109	8	18.02	20	46.02	50	**3.98**
59	110	8	21.84	10	39.84	45	**5.16**
60	111	7	23.42	10	40.42	50	**9.58**
61	114	8	23.55	7	38.55	50	**11.45**
62	116	8	28.45	7	43.45	60	**16.55**
63	117	9	16.1	7	32.1	40	**7.9**
64	119	10	22.89	6	38.89	50	**11.11**
65	120	8	33.97	9	50.97	67	**16.03**
66	123	9	25.03	7	41.03	55	**13.97**
67	125	8	32.23	8	48.23	68	**19.77**
68	127	10	36.52	7	53.52	75	**21.48**
69	128	8	30.57	10	48.57	60	**11.43**
70	130	10	31.6	9	50.6	60	**9.4**
71	133	6	26.8	9	41.8	60	**18.2**
72	135	8	25.45	6	39.45	55	**15.55**
73	136	9	24.92	6	39.92	52	**12.08**
74	138	10	34.67	13	57.67	75	**17.33**
75	140	9	28.45	7	44.45	60	**15.55**
76	142	9	34.6	6	49.6	70	**20.4**
77	144	5	30.77	7	42.77	60	**17.23**
78	145	8	23.55	10	41.55	57	**15.45**
79	146	6	14.17	30	50.17	60	**9.83**

80	149	9	27.35	9	45.35	67	**21.65**
81	151	10	38.15	8	56.15	80	**23.85**
82	152	8	24.17	10	42.17	50	**7.83**
83	153	9	15.15	9	33.15	40	**6.85**
84	154	8	18.02	23	49.02	45	**-4.02**
85	156	7	27.35	10	44.35	55	**10.65**
86	157	10	12.15	12	34.15	37	**2.85**
87	160	7	47.57	8	62.57	90	**27.43**
88	161	8	15.4	7	30.4	33	**2.6**
89	162	15	21.84	6	42.84	53	**10.16**
90	164	9	28.64	10	47.64	65	**17.36**
91	165	8	21.12	10	39.12	52	**12.88**
92	167	10	14.63	8	32.63	38	**5.37**
93	169	8	12.76	12	32.76	38	**5.24**
94	170	6	23.07	7	36.07	52	**15.93**
95	171	9	21.05	12	42.05	50	**7.95**
96	173	10	13.5	8	31.5	37	**5.5**
97	175	8	36.32	10	54.32	68	**13.68**
98	176	8	17.1	10	35.1	45	**9.9**
99	178	7	17.59	8	32.59	40	**7.41**
100	180	8	13.43	9	30.43	37	**6.57**
101	181	5	8.3	8	21.3	23	**1.7**
102	183	10	17.06	8	35.06	43	**7.94**
103	185	7	18.99	10	35.99	45	**9.01**
104	187	10	18.02	27	55.02	68	**12.98**
105	188	6	32.09	10	48.09	67	**18.91**
106	192	30	21.84	7	58.84	70	**11.16**
107	194	6	18.45	9	33.45	40	**6.55**
108	195	9	18.68	12	39.68	52	**12.32**

109	197	10	15.4	6	31.4	37	**5.6**
110	199	7	29.23	10	46.23	60	**13.77**
111	201	7	32.67	9	48.67	65	**16.33**
112	202	9	32.03	13	54.03	67	**12.97**
113	204	8	38.95	22	68.95	90	**21.05**
Total							**1373.39**
TT saving/passenger							**12.15**

APPENDIX A-02: Motor Bike TT Calculation

Sr. No	Survey form No:	Current TT (Minutes)				Previous TT (Minutes)	TT saving (Minutes)
		Home/w.place to BRT stn	Stn to stn time	BRT stn to home/W.Place	Total TT		
1	11	10	43.69	15	68.69	45	-23.69
2	20	10	5.48	5	20.48	15	-5.48
3	23	5	23.93	15	43.93	20	-23.93
4	35	5	25.34	7	37.34	30	-7.34
5	40	5	21.19	4	30.19	20	-10.19
6	45	8	21.19	5	34.19	25	-9.19
7	51	15	9.76	12	36.76	30	-6.76
8	54	10	40.52	15	65.52	55	-10.52
9	56	10	29.23	8	47.23	45	-2.23
10	59	10	26.55	15	51.55	40	-11.55
11	60	5	19.29	10	34.29	30	-4.29
12	61	8	24.92	8	40.92	35	**-5.92**
13	66	10	22.89	12	44.89	30	**-14.89**
14	67	8	38.1	10	56.1	50	**-6.1**
15	68	8	19.15	8	35.15	28	**-7.15**
16	76	12	15.69	6	33.69	28	**-5.69**
17	78	10	30.35	6	46.35	35	**-11.35**
18	86	8	18.58	7	33.58	25	**-8.58**
19	87	10	30.78	10	50.78	35	**-15.78**
20	88	15	28.93	8	51.93	35	**-16.93**
21	95	6	18.99	7	31.99	20	**-11.99**
22	103	8	19.27	5	32.27	30	**-2.27**
23	108	5	19.17	8	32.17	20	**-12.17**
24	113	6	13.9	12	31.9	20	**-11.9**
25	118	7	36.27	7	50.27	40	**-10.27**

26	126	7	19.23	6	32.23	20	**-12.23**
27	134	8	22.97	8	38.97	25	**-13.97**
28	141	8	21.84	7	36.84	23	**-13.84**
29	143	7	21	9	37	25	**-12**
30	148	7	20.89	7	34.89	22	**-12.89**
31	159	8	21.05	9	38.05	28	**-10.05**
32	163	8	17.06	8	33.06	20	**-13.06**
33	179	9	21	6	36	25	**-11**
34	186	8	27.35	8	43.35	30	**-13.35**
35	193	9	28.93	12	49.93	38	**-11.93**
36	196	8	26.74	6	40.74	30	**-10.74**
Total							**-391.22**
TT saving/passenger							**-10.87**

APPENDIX A-03: Own Vehicle TT Calculation

Sr. No:	Survey form No:	Current TT (Minutes)				Previous TT (Minutes)	TT saving (Minutes)
		Home/w.place to BRT stn	Stn to stn time	BRT stn to home/W.Place	Total TT		
1	3	8	33.97	15	56.97	37	**-19.97**
2	7	7	24.82	10	41.82	15	**-26.82**
3	16	10	43.69	20	73.69	75	**1.31**
4	17	10	21.19	8	39.19	30	**-9.19**
5	25	10	43.69	10	63.69	45	**-18.69**
6	28	5	31.34	15	51.34	25	**-26.34**
7	34	5	29.85	10	44.85	40	**-4.85**
8	37	20	43.69	30	93.69	80	**-13.69**
9	39	6	4.18	8	18.18	15	**-3.18**
10	72	10	24.95	7	41.95	25	**-16.95**
11	79	8	29.17	7	44.17	35	**-9.17**
12	89	8	32.23	8	48.23	38	**-10.23**
13	97	8	19.45	7	34.45	25	**-9.45**
14	104	9	25.14	8	42.14	30	**-12.14**
15	115	7	17.06	7	31.06	20	**-11.06**
16	122	7	20.89	8	35.89	22	**-13.89**
17	129	7	18.8	7	32.8	17	**-15.8**
18	137	8	20.89	9	37.89	20	**-17.89**
19	150	5	12.76	10	27.76	15	**-12.76**
20	155	10	18.8	8	36.8	18	**-18.8**
21	168	9	21.19	6	36.19	18	**-18.19**
22	177	10	19.45	9	38.45	22	**-16.45**
23	189	8	23.42	7	38.42	27	**-11.42**
24	200	8	17.06	7	32.06	20	**-12.06**

Total	**-327.68**
TT saving/passenger	**-13.65**

APPENDIX A-04: Taxi TT Calculation

Sr. No	Survey form No:	Current TT (Minutes)				Previous TT (Minutes)	TT saving (Minutes)
		Home/w.place to BRT stn	Stn to stn time	BRT stn to home/W.Place	Total TT		
1	4	22	41.95	10	73.95	65	**-8.95**
2	13	10	41.77	20	71.77	60	**-11.77**
3	30	8	9.76	5	22.76	20	**-2.76**
4	31	10	14.5	25	49.5	37	**-12.5**
5	43	5	16.45	8	29.45	30	**0.55**
6	69	12	16.45	5	33.45	25	**-8.45**
7	74	5	17.27	12	34.27	30	**-4.27**
8	81	7	21.19	10	38.19	35	**-3.19**
9	92	7	11.63	10	28.63	20	**-8.63**
10	96	10	32.49	5	47.49	35	**-12.49**
11	99	8	12.92	5	25.92	20	**-5.92**
12	112	8	14.02	8	30.02	25	**-5.02**
13	121	7	18.58	6	31.58	25	**-6.58**
14	131	8	21	9	38	23	**-15**
15	139	7	22.89	8	37.89	27	**-10.89**
16	147	8	21.19	8	37.19	25	**-12.19**
17	158	6	19.27	9	34.27	22	**-12.27**
18	166	7	19.39	9	35.39	23	**-12.39**
19	172	7	26.55	9	42.55	32	**-10.55**
20	174	9	17.09	7	33.09	28	**-5.09**
21	184	9	14.02	9	32.02	25	**-7.02**
22	191	7	19.45	8	34.45	27	**-7.45**
23	198	7	30.19	8	45.19	37	**-8.19**
24	203	8	19.45	10	37.45	27	**-10.45**
25	205	10	16.95	6	32.95	27	**-5.95**

Total	**-207.42**
TT saving/passenger	**-8.30**

APPENDIX A-05: Rickshaw TT Calculation

Sr. No:	Survey form No:	Current TT (Minutes)				Previous TT (Minutes)	TT saving (Minutes)
		Home/w.place to BRT stn	Stn to stn time	BRT stn to home/W.Place	Total TT		
1	63	10	7.35	7	24.35	20	**-4.35**
2	82	9	14.17	6	29.17	25	**-4.17**
3	106	5	18.02	5	28.02	25	**-3.02**
4	124	8	16.52	10	34.52	30	**-4.52**
5	132	8	16.52	12	36.52	28	**-8.52**
6	182	7	15.4	7	29.4	25	**-4.4**
7	190	9	16.52	9	34.52	28	**-6.52**
Total							**-35.5**
TT saving/passenger							**-5.07**

APPENDIX-B: Average Monthly Nominal Wage Rate of Pakistan

Appendix Table 1: Average Monthly Nominal Wages by Industry by Sex 1990/91–2006/07 (All Employees)

Sex	Industry	1990-91	1991-92	1993-94	1996-97	1997-98	1999-00	2001-02	2003-04	2005-06	2006-07
Male	1 Agriculture	1161.97	1663.12	1374.74	2258.33	2190.82	2273.79	1245.16	2578.49	3157.55	3997.92
	2 Mining & Quarrying	1333.16	1605.37	1665.28	4566.30	3923.24	2772.35	5669.71	5519.01	4115.41	6338.52
	3 Manufacturing	1491.02	1840.86	2181.84	3126.83	3518.86	3297.59	2948.36	4034.04	4675.86	6025.99
	4 Electric Gas & Water	1747.59	2211.34	2672.53	4197.77	4510.40	4685.34	6032.22	6469.75	8277.90	10468.8
	5 Construction	1228.14	1416.26	1770.67	2484.10	2746.62	2771.85	902.17	3178.73	4100.57	4941.46
	6 Wholesale & Retail Trade	1335.89	1492.19	1981.11	2687.57	3002.93	2805.10	2695.59	3128.46	3933.22	4772.95
	7 Transportation	1556.67	1858.16	2326.95	3495.88	3598.97	3610.70	3496.52	4848.17	5530.44	6469.93
	8 Financial Real estate	3096.07	4068.84	5203.04	7956.95	8404.50	10065.90	13277.06	12474.75	13825.79	13806
	9 Other	1546.43	1902.38	2307.86	3373.10	3767.88	3775.64	3882.34	5189.76	6708.66	7835.97
	Total	**1462.70**	**1792.73**	**2119.57**	**3162.50**	3387.93	3374.23	3011.13	4278.24	5246.00	6338.14
Female	1 Agriculture	593.88	647.64	711.83	1293.38	1458.56	1169.72	324.81	1619.08	1489.61	1644.41
	2 Mining & Quarrying	1283.33	782.89			8000.00	2760.00	1000.00	1774.76	2443.02	40000
	3 Manufacturing	770.78	932.20	1100.72	1758.82	1854.82	1761.05	855.14	1684.88	2068.37	2443.49
	4 Electric Gas & Water	1898.07	1889.64	1681.25	3098.18	5069.83	2477.63	7993.10	6155.68	8512.22	9511.18
	5 Construction	1101.11	1113.79	1750.48	2139.20	2466.26	1628.90	618.45	1858.96	3321.43	2867.3
	6 Wholesale & Retail Trade	1172.28	921.71	1357.18	2048.18	3693.10	3643.06	2072.63	3362.17	3756.84	4369.62
	7 Transportation	1465.33	2013.45	2597.05	2254.24	3673.12	4378.04	4773.03	5141.73	6066.83	5505.76
	8 Financial Real estate	2646.76	3320.42	5083.76	3643.65	7122.12	14193.23	18962.01	9385.26	12454.93	17350.1
	9 Other	1199.36	1501.87	1847.08	2320.88	2609.20	2988.81	2902.75	3752.06	4983.05	5354.84
	Total	**944.29**	**1065.90**	**1330.88**	**1885.56**	2257.40	2033.18	1538.33	2595.10	3348.97	3625.74
Pakistan	1 Agriculture	1048.33	1391.75	1225.41	1940.52	2030.31	1879.53	879.59	2200.61	2616.45	3173.66
	2 Mining & Quarrying	1332.12	1575.73	1665.28	4566.30	4029.99	2771.59	5518.98	5261.53	4068.48	6629.68
	3 Manufacturing	1414.09	1733.74	2050.73	3003.47	3412.44	3178.25	2709.19	3762.21	4307.38	5537.48
	4 Electric Gas & Water	1749.07	2206.78	2665.29	4191.46	4521.92	4661.68	6064.63	6465.66	8279.11	10456.2
	5 Construction	1225.99	1412.60	1770.44	2480.09	2743.96	2757.25	900.68	3169.05	4091.12	4913.37
	6 Wholesale & Retail Trade	1332.77	1475.57	1962.95	2678.83	3009.36	2816.89	2688.56	3130.95	3929.44	4767.1
	7 Transportation	1555.34	1859.59	2331.02	3481.67	3600.40	3617.34	3507.48	4849.63	5537.80	6461.52
	8 Financial Real estate	3082.20	4044.25	5200.15	7930.06	8352.63	10205.91	13320.38	12433.15	13761.30	13919.2
	9 Other	1494.75	1843.48	2245.23	3174.33	3569.54	3643.12	3697.93	4895.20	6350.09	7346.83
	Total	**1411.87**	**1712.89**	**2038.22**	**3006.12**	3279.56	3198.83	2810.40	4044.68	4991.61	5983.69

Note: i. Based on Individual data tabulation - Labour Force Surveys of Various Years.
ii. Real Wages are worked using the Consumer Price Index with 2000-01=100 as reported in Pakistan Economics Survey (PSE) 2007-08.

APPENDIX-C: Consumer Price Index (CPI) of Pakistan

APPENDIX D-01: 24-Hours Traffic Count Data of Murree Road (After BRTS)

SERIAL No	TIME (HOURS) FROM	TIME (HOURS) TO	NON - MOTORIZED: ANIMAL DRAWN	NON - MOTORIZED: BICYCLE	M O T O R I Z E D: MOTOR CYCLES	RICK-SHAWS	CARS JEEP	PAJERO/ SUZUKI PICK-UPS	TAXI	HIACE WAGON	MINI BUS/ COASTER	BUSES	LOADER PICKUP	TRUCKS	HOURLY TOTAL TRAFFIC
			1	2	3	4	5	6	7	8	9	10	11	12	
1	7	8	15	76	942	51	1771	335	501	20	25	76	107	2	**3921**
2	8	9	25	83	2097	72	3285	289	694	26	12	31	187	10	**6811**
3	9	10	14	58	1377	81	3016	197	669	21	5	15	222	21	**5697**
4	10	11	8	46	1596	64	3427	220	1161	25	5	11	299	15	**6877**
5	11	12	2	51	1196	60	3006	319	652	29	3	9	280	7	**5614**
6	12	13	9	19	1034	71	2140	207	792	25	1	13	212	8	**4531**
7	13	14	2	21	1007	72	3553	232	702	23	3	8	281	6	**5909**
8	14	15	5	16	467	107	3043	216	842	28	9	15	191	9	**4947**
9	15	16	5	11	747	74	2664	246	616	36	8	21	212	11	**4652**
10	16	17	8	24	768	47	3136	198	486	48	20	59	211	6	**5011**
11	17	18	10	28	487	116	2481	293	482	38	18	49	238	4	**4245**
12	18	19	4	18	543	68	3262	200	517	26	5	12	280	5	**4941**
13	19	20	3	11	677	53	2570	160	277	25	4	10	181	4	**3974**
14	20	21	0	8	716	46	2604	245	323	24	4	5	168	3	**4146**
15	21	22	3	3	389	22	1951	200	238	11	8	5	140	7	**2977**
16	22	23	0	3	331	19	1935	135	248	10	8	8	110	37	**2844**
17	23	24	1	1	176	14	993	87	127	5	3	1	66	35	**1509**
18	24	1	0	0	85	2	402	35	49	1	0	1	38	16	**629**
19	1	2	0	0	54	1	294	25	33	1	0	0	40	28	**476**
20	2	3	0	0	36	0	203	11	20	1	0	0	21	18	**310**
21	3	4	0	0	22	0	206	7	19	0	0	0	12	20	**286**
22	4	5	0	0	16	0	180	17	15	1	1	1	10	2	**243**
23	5	6	0	0	49	1	242	13	35	2	6	3	24	3	**378**
24	6	7	0	36	271	11	436	99	183	37	19	53	73	7	**1225**
TOTAL			114	513	15083	1052	46801	3986	9682	463	167	406	3603	284	**82153**

APPENDIX D-02: 24-Hours Traffic Count Data of Murree Road (Before BRTS)

SERIAL No	TIME (HOURS) FROM	TO	NON - MOTORIZED ANIMAL DRAWN	BICYCLE	M O T O R I Z E D MOTOR CYCLES	RICK-SHAWS	CARS JEEP	PAJERO/ SUZUKI PICK-UPS	TAXI	HIACE WAGON	MINI BUS/ COASTER	BUSES	LOADER PICKUP	TRUCKS	HOURLY TOTAL TRAFFIC
			1	2	3	4	5	6	7	8	9	10	11	12	
1	7	8	5	86	1111	53	1948	361	550	332	76	78	101	2	**4705**
2	8	9	14	84	2512	74	3619	306	764	310	40	21	174	10	**7930**
3	9	10	6	40	1633	81	3330	210	734	221	8	3	199	21	**6486**
4	10	11	5	33	1911	64	3792	234	1295	299	5	6	279	15	**7938**
5	11	12	2	26	1406	60	3314	346	716	315	6	4	258	6	**6459**
6	12	13	6	9	1216	70	2358	222	879	238	3	9	190	7	**5206**
7	13	14	3	6	1175	74	3927	250	780	453	5	4	267	6	**6951**
8	14	15	10	19	548	110	3358	231	936	267	20	27	171	9	**5708**
9	15	16	7	12	864	75	2939	261	680	251	18	10	204	11	**5332**
10	16	17	3	9	893	46	3468	215	538	352	46	50	197	6	**5824**
11	17	18	5	16	562	116	2727	320	522	319	50	25	207	7	**4877**
12	18	19	2	13	630	64	3609	213	562	245	6	20	258	5	**5628**
13	19	20	1	8	785	52	2834	172	296	211	8	6	166	4	**4544**
14	20	21	1	5	827	47	2847	261	352	270	8	11	146	2	**4778**
15	21	22	1	1	451	23	2152	213	263	194	10	9	126	2	**3445**
16	22	23	0	0	374	19	2133	144	275	146	16	4	116	34	**3261**
17	23	24	0	1	184	15	1089	93	139	63	4	2	73	37	**1700**
18	24	1	0	0	85	8	440	34	53	23	0	1	58	15	**717**
19	1	2	0	0	49	1	308	25	37	14	0	0	57	31	**523**
20	2	3	0	0	37	0	213	13	23	5	0	0	29	16	**337**
21	3	4	0	8	25	0	218	8	21	1	0	1	15	19	**316**
22	4	5	0	1	19	0	195	18	19	0	1	2	12	3	**270**
23	5	6	0	0	53	1	265	14	39	43	17	14	30	0	**476**
24	6	7	0	43	299	12	470	107	195	153	43	68	55	4	**1447**
TOTAL			72	420	17651	1065	51553	4270	10670	4726	391	376	3390	272	**94854**

APPENDIX E: BRTS Capital Cost Data

Red Line Revenue and Subsidy			
	Amount (Rs)	**Unit**	**Cost (Million Rs)**
Capital Cost of Construction of MBS Infrastructure			40,000
Vehicle Cost (Articulated Bus)	30	Million Rs/Bus	
Cost of Bus	30	Million Rs/Bus	
Cost of 68 Buses			2,040
Vehicle Running +Operational +including bus Cost & Maintenance	300	Rs/km	
Bus km per Year	9,232,704	km	
Cost of Bus Operations (Annual)			**2,000**
		Total	**44,040**

APPENDIX F: Compound Interest Rate Factors

	Single Payment		Uniform Payment Series				Arithmetic Gradient	
N	Compound Amount Factor: Find *F* Given *P* *F/P*	Present Worth Factor: Find *P* Given *F*, *P/F*	Sinking Fund Factor: Find *A* Given *F*, *A/F*	Capital Recovery Factor: Find *A* Given *P*, *A/P*	Capital Amount Factor: Find *F* Given *A*, *F/A*	Present Worth Factor: Find *P* Given *A*, *P/A*	Gradient Uniform Series: Find *A* Given *G*, *A/G*	Gradient Present Worth: Find *P* Given *G*, *P/G*
40	7.040	0.1420	0.0083	0.0583	120.800	17.159	13.377	229.545
45	8.985	0.1113	0.0063	0.0563	159.700	17.774	14.364	255.315
50	11.467	0.0872	0.0048	0.0548	209.348	18.256	15.223	277.915
55	14.636	0.0683	0.0037	0.0537	272.713	18.633	15.966	297.510
60	18.679	0.0535	0.0028	0.0528	353.584	18.929	16.606	314.343
65	23.840	0.0419	0.0022	0.0522	456.798	19.161	17.154	328.691
70	30.426	0.0329	0.0017	0.0517	588.529	19.343	17.621	340.841
75	38.833	0.0258	0.0013	0.0513	756.654	19.485	18.018	351.072
80	49.561	0.0202	0.0010	0.0510	971.229	19.596	18.353	359.646
85	63.254	0.0158	0.0008	0.0508	1,245.087	19.684	18.635	366.801
90	80.730	0.0124	0.0006	0.0506	1,594.607	19.752	18.871	372.749
95	103.035	0.0097	0.0005	0.0505	2,040.694	19.806	19.069	377.677
100	131.501	0.0076	0.0004	0.0504	2,610.025	19.848	19.234	381.749
				6%				
1	1.060	0.9434	1.0000	1.0600	1.000	0.943	0.000	0.000
2	1.124	0.8900	0.4854	0.5454	2.060	1.833	0.485	0.890
3	1.191	0.8396	0.3141	0.3741	3.184	2.673	0.961	2.569
4	1.262	0.7921	0.2286	0.2886	4.375	3.465	1.427	4.946
5	1.338	0.7473	0.1774	0.2374	5.637	4.212	1.884	7.935
6	1.419	0.7050	0.1434	0.2034	6.975	4.917	2.330	11.459
7	1.504	0.6651	0.1191	0.1791	8.394	5.582	2.768	15.450
8	1.594	0.6274	0.1010	0.1610	9.897	6.210	3.195	19.842
9	1.689	0.5919	0.0870	0.1470	11.491	6.802	3.613	24.577
10	1.791	0.5584	0.0759	0.1359	13.181	7.360	4.022	29.602
11	1.898	0.5268	0.0668	0.1268	14.972	7.887	4.421	34.870
12	2.012	0.4970	0.0593	0.1193	16.870	8.384	4.811	40.337
13	2.133	0.4688	0.0530	0.1130	18.882	8.853	5.192	45.963
14	2.261	0.4423	0.0476	0.1076	21.015	9.295	5.564	51.713
15	2.397	0.4173	0.0430	0.1030	23.276	9.712	5.926	57.555
16	2.540	0.3936	0.0390	0.0990	25.673	10.106	6.279	63.459
17	2.693	0.3714	0.0354	0.0954	28.213	10.477	6.624	69.401
18	2.854	0.3503	0.0324	0.0924	30.906	10.828	6.960	75.357
19	3.026	0.3305	0.0296	0.0896	33.760	11.158	7.287	81.306
20	3.207	0.3118	0.0272	0.0872	36.786	11.470	7.605	87.230
21	3.400	0.2942	0.0250	0.0850	39.993	11.764	7.915	93.114
22	3.604	0.2775	0.0230	0.0830	43.392	12.042	8.217	98.941
23	3.820	0.2618	0.0213	0.0813	46.996	12.303	8.510	104.701
24	4.049	0.2470	0.0197	0.0797	50.816	12.550	8.795	110.381
25	4.292	0.2330	0.0182	0.0782	54.865	12.783	9.072	115.973

APPENDIX G-1: Filled Survey Form-I

NATIONAL UNIVERSITY OF SCIENCES AND TECHNOLOGY (NUST) ISLAMABAD.

(1)

QUESTIONNAIRE SURVEY FORM

Date: 25 / 05 /2016. **Time:** 4 : 20 **Gender:** ☑ Male ☐ Female

BRT station Origin: Faiz Abad **BRT station Destination:** Liaqat Bagh

1. What is your education level?
☐ Below matric ☐ Matric ☑ FA/FSc
☐ BSc/BS ☐ MS/M.Phil ☐ PhD.

2. What is your occupation?
☐ Student ☐ Unemployed
☐ Govt. Employ ☐ Laborer
☐ Other Electrician

3. What is your monthly income?
☑ < 20K ☐ 20K-30K ☐ 30K-40K
☐ 40K-50K ☐ 50K-60K ☐ 60K-70K
☐ 70K-80K ☐ 80K-90K ☐ > 90K.

4. What is the purpose of your trip?
☐ Education ☑ Work ☐ Medical
☐ Shopping ☐ Social ☐ ______

5. How many days a weak you use BRT service?
☑ ≥ 5 ☐ 3-4 ☐ 1-2
☐ Occasionally.

6. Do you own your own vehicle?
☐ Yes ☑ No

7. If yes, then why don't you use your own vehicle?
Ans: /

8. What was your previous mode of transportation?
☐ Walk ☐ Motor bike ☐ Own vehicle
☐ Taxi ☑ Public transport ☐ ______

9. What was your previous route?
Ans: PuT (1 number wagon).

10. How much time it used to take from your home/workplace (origin) to your home/workplace (destination) before BRTS? (Minutes).
☐ < 30 ☑ 30-45 ☐ 45-60
☐ 60-75 ☐ 75-90 ☐ 90-105
☐ 105-120 ☐ 120-150 ☐ > 150.

11. How much time it takes to reach BRT station from your home/workplace? (Minutes).
5 ☑ < 10 ☐ 10-20 ☐ 20-30
☐ 30-40 ☐ 40-50 ☐ > 50.

12. How much time it takes to reach your home/workplace from BRT station? (Minutes).
☐ < 10 ☑ 10-20 ☐ 20-30
☐ 30-40 ☐ 40-50 ☐ > 50.

13. How do you come to/go from BRT station to your origin/destination?
☑ Walk ☐ Motor bike ☐ Own vehicle
☐ Taxi ☐ Public transport ☐ ______

14. How much is your current travelling cost?
Ans: 20 (Rs.)

15. How much was your previous travelling cost?
Ans: 20 (Rs.)

16. What is your opinion about the buses Headway (frequency)?
☐ Should be increased ☑ Reasonable
☐ Should be decreased.

17. What is your current safety perception?
☐ Excellent ☑ Satisfactory ☐ Poor

18. What is your previous safety perception?
☐ Excellent ☐ Satisfactory ☑ Poor

19. What is your satisfactory level about BRT construction?
☐ Excellent ☑ Good ☐ Satisfactory
☐ Poor ☐ Very poor.

20. Any suggestion:
/

APPENDIX G-2: Filled Survey Form-II (WTP Survey)

(1)

National University of Sciences and Technology (NUST) Islamabad

WILLINGNESS TO PAY SURVEY

Date: 31/8/2016. **Time:** 3 : 15 **Gender:** ☑ Male ☐ Female

1. What is your income level? (Rs.)

☐ <20K ☐ 20K-30K

☐ 30K-40K ☑ 40K-50K

☐ >50K

2. What was your previous Mode?

☐ Own vehicle ☐ Motor Bike

☑ Public transport ☐ Taxi

☐ Other: __________.

3. How much fare did you pay before BRTS? (Rs.)

☐ 10-15 ☑ 15-20 ☐ 20-25

☐ 25-30 ☐ 30-35 ☐ 35-40

☐ 40-45 ☐ 45-50 ☐ >50

4. What do you say about BRTS fare?

☐ Should be decreased.

☑ Reasonable.

☐ Should be increased.

5. If BRTS fare has to be increased, how much you are willing to pay? (Rs.)

☐ 20 ☐ 23 ☐ 25 ☑ 30

☐ 33 ☐ 35 ☐ 38 ☐ 40

☐ 45 ☐ 50 ☐ >50