IMPACT OF BRT ON TRAVEL CONDITIONS ON ADJACENT MAJOR CORRIDOR: A REVEALED TRAVEL TIME IMPACT ANALYSIS

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A thesis submitted to the National University of Sciences and Technology, Islamabad,

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Transportation Engineering

Thesis supervisor: Dr. Muhammad Asif Khan

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THESIS ACCEPTANCE CERTIFICATE

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DEDICATION

Dedicated to my exceptional father whose urge for acquiring higher education, to my loving mother whose comforting me through hard times and always believing in me and my adored siblings whose enormous persistent support and cooperation helped me attain this accomplishment.

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(Engr. Mian M. Wasim Kakakhel)

ABSTRACT

Traffic congestion is a major urban transportation issue as it can be a barrier to economic growth. One potential solution to the issue of urban road traffic congestion is effective public transportation (PT). As the 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, this not only affect the traffic, but have negative impacts on environment, economy, and social well-being of people as well. There are several strategies for reducing congestion that can be used to deal with such issues. The establishment of mass transit systems (MTS) has proven to be a very effective strategy, with the Bus Rapid Transit System (BRTS) emerging as a preeminent one.

The Government of Khyber Pakhtunkhwa asked the Cities Development Initiative for Asia for technical assistance in 2013 to upgrade Peshawar's disorganized, poorly managed, and deteriorating urban transportation system. Since Peshawar’s University Road is the busiest route of Peshawar city when millions of people rush for their daily life activities for almost the whole day. The users faced serious issues in terms of travel time, congestion, and pollution. Therefor It was suggested that the Bus Rapid Transit (BRT) project be built to address this issue. Thus, BRT Peshawar project began in 2017 under the Peshawar Development Authority (PDA). The system became fully operational in August 2020. Since there are many studies that focuses on the evaluation of BRT projects, research on impact of BRT on adjacent roads have received little to no attention. So, after the inauguration of Bus Rapid Transit (BRT) in Peshawar there’s a need to find out whether it has improved the travel conditions of city or not. The evaluation framework comprised of three main MOEs which include vehicle operating cost (VOC), fuel emissions and level of service (LOS) of the road users and vehicles travelling on adjacent road to BRT. For this analysis two scenarios were formed. First one was finding all the above mentioned MOEs for with BRT condition. Second condition was without BRT.

Ultimately, based on the findings of the analysis, it was concluded that BRT Peshawar has brought positive and beneficial impacts in terms of vehicle operating cost (VOC), fuel emissions and level of Service (LOS) for the condition in which BRT project was inaugurated. The vehicle operating cost (VOC) has reduced by 15.3% while using a Hepburn model. Similarly, a decrease of 26.3% was seen while using the NTRC values for the condition that included BRT. While carbon monoxide (CO) has decreased by 24% for the scenario when BRT was inaugurated. Whereas the quantity of nitrous oxide (NOx) and Hydrocarbon (HC) have remained stagnated at the level for both the scenarios i.e. with and without BRT. While the university road observed an improvement in the LOS for both the directions when BRT was introduced. LOS in Direction-1 improved from F to D, while direction-3 has seen an increase from B to A after the construction and operation of BRT.

Keywords: Vehicle Operating Cost (VOC), Level of Service (LOS), Bus Rapid Transit (BRT), Measure of Effectiveness (MOEs), National Transport and Research Centre (NTRC)

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LIST OF ABBREVIATIONS

BRT	-	Bus Rapid Transit
BRTS	-	Bus Rapid Transit System
PT	-	Public Transport
MTS	-	Mass Transit System
VOC	-	Vehicle Operating Cost
LOS	-	Level of Service
PDA	-	Peshawar Development Authority
NTRC	-	National Transport Research Centre
MOEs	-	Measure of Effectiveness
BPR	-	Bureau of Public Roads
HCM	-	Highway Capacity Manual
FFS	-	Free Flow Speed
PCU	-	Passenger Car Unit
PCE	-	Passenger Car Equivalent

CHAPTER 1: INTRODUCTION

1.1 GENERAL

Metropolitan areas and big cities have always been the focus and concentration of major activities and have been the hub of national economy. These large cities host the majority of the nation's economic activities. Being the hub of activities, these cities draw a lot of people, which complicates the spatial urban structures. The socio-economic structure, land use, and demographics of urban areas change as a result of the population shift to large cities. The general ambiance of the city is disturbed by these changes. Motorization and urbanization are the main indicators of this flux of people. Because of that the streets and roads of major cities around the world are becoming extremely congested, and the transportation system is becoming unstable. These have an adverse effect on the environment, the economy, and the social well-being of people in addition to having an adverse effect on traffic. Traffic congestion result in delays, mental and physical disruption, higher vehicle operating costs, more air and noise pollution, rapid deterioration of the road surface, etc. There are several strategies for reducing congestion that can be used to deal with such issues. The introduction of intelligent transportation systems (ITS), grade separated intersections, congestion pricing, the launch of mass transit programs, and other traffic-calming measures may be some of these major strategies. The strategy for this study is the implementation of mass transit program. A mass transit system (MTS), also known as public transport, is a shared service for moving people using various modes of transportation, including wagons, buses, trams, rapid transit buses, metro rails, and ferries, among others. The people can choose mass transit system (MTS) because it is reasonably an affordable option.

People in developing nations like Pakistan primarily depend on public transport for daily transportation needs. Urban areas in developing countries like Pakistan have a mix of traffic patterns, a high population density, a mixed pattern of land use, higher ratio of non-motorized vehicles, shorter trip distances and poor public transport facilities. The general public's use of private vehicle has seen an increase in urban areas due to the general lack of poor public transportation facilities. Urban roads now have higher traffic densities and a congested urban road network system as a result of this increased motorization. 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). In the past, government officials attempted to improve public transportation buses in order to relieve congestion, but these efforts failed to produce satisfactory results. Now it has been realized that the system can be well managed by improving both the buses as well as road infrastructure. Therefore, it was determined that an organized and managed mass transit system (MTS) is a suitable option to be implemented. Because of this, the government decided to launch various mass transit services. The government introduced the Bus Rapid Transit System (BRTS), which is a highly effective form of mass transit. Because of how affordable it is to build, run, and maintain, it has become a popular form of public transportation in many nations around the world. (Sharma et al., 2012). A bus-based transit system, or BRTS, offers quick, inexpensive, comfortable, affordable, and environmentally friendly mode of transportation for the general public. A bus rapid transit (BRT) has priority at intersections and uses designated bus lanes. Because of this, the rapid bus transit system is quickly gaining popularity in underdeveloped countries.

The first project of this kind in Pakistan was launched in Lahore, the provincial capital of Punjab. The public responded positively to this initiative, which is now operating successfully. 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. The construction work of this project started in February 2014 and was completed in June 2015. The third similar project in Pakistan was of Multan Metro Bus. It began its operation in January 2017. However, in order to improve Peshawar's chaotic, mismanaged and outdated urban transportation system in Peshawar, the Government of Khyber Pakhtunkhwa asked the Cities Development Initiative for Asia for technical assistance in 2013. (Development Bank, 2017). Construction of the Bus Rapid Transit (BRT) project was proposed in order to resolve this problem. Thus BRT Peshawar project began in 2017 under the Peshawar Development Authority (PDA). The system became fully operational in August 2020. This BRT project was aimed to provide a rapid, economical, comfortable, affordable and environmentally compatible mean of transportation to the public. It was also assumed that this BRT project will reduce 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 sustainable public transport service. These were the goals and objectives of implementation of BRT Peshawar.

Now the point of concern is that whether this BRT project is fulfilling the goals and objectives, for which it was implemented. With this background and keeping the goals and objectives of BRT project in mind, this research study was carried out to evaluate and assess the impact of BRT project on travel conditions on adjacent major corridor of the city. The focus of the study was to assess and evaluate the vehicle operating cost (VOC), fuel emissions and level of service (LOS) for the two scenarios i.e. if BRT wasn't constructed in 2021 and for current condition where BRT is inaugurated.

1.2 PROBLEM STATEMENT

According to the 2017 census, Peshawar, the provincial capital of Khyber Pakhtunkhwa (KPK), had a population of 4.26 million (GOP, 2017). Peshawar city occupies a strategic location as a commercial hub, serving as a gateway to Afghanistan and a link between countries in Central Asia and the Middle East. Private modes of transportation have greatly increased over the past few decades; for example, the number of private cars has climbed by 229 percent in the past ten years (Arshad & Khan, 2015). The city of Peshawar's road network is congested with private vehicles as a result of this increase, which also causes pollution and traffic accidents. At the same time, Peshawar 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.

After looking at all the issues, the Khyber Pakhtunkhwa government started thinking to resolve these issues. Hence, it was proposed to carry out a mass transit system (MTS) for the city. So, a Bus Rapid Transit (BRT) system was propped to be a suitable option of MTS. The construction of this project started in 2017 and was completed in 2020 and currently the project is operating successfully. It has a 26km long corridor with 31 stations, each station being 850m apart on average. 15km of the corridor is at grade, 8km is a flyover, and the final 3km is an underpass. (*TransPeshawar Overview – Zu Peshawar*, n.d.).

Now it is claimed that the BRT is a fast, comfortable, sustainable, safe and an economical option of public transportation but while there are many studies focusing on the benefits of BRT, research on congestion impacts, a fundamental component of any analysis of transport performance, associated with BRT has received little attention in developing countries. Keeping in view the above points, it becomes very important to know that what are the potential impact of BRT on the travel condition on adjacent major corridor.

Above discussed points validate the need to carry out a research study to evaluate the impact of BRT on travel conditions on adjacent major corridor by finding out the vehicle operating cost (VOC) of road users, fuel emissions and level of service (LOS) for both the scenarios i.e. if there wasn't BRT in year 2021 and if there is a BRT constructed and operationalized in 2021. So, in this research study, an effort has been made to assess and evaluate the impact of BRT Peshawar and help agencies and decision makers on the feasibility of such proposed projects.

1.3 RESEARCH OBJECTIVES

The objectives of the research study are as follows:

- To quantify user's cost for with and without BRT scenarios.
- To determine the fuel emissions for both the scenarios i.e. with and without BRT project.
- To assess the level of service of road network for both the scenarios.

1.4 SCOPE OF RESEARCH

Due to rapid increase in population in urban areas of Pakistan, there is a serious congestion problem on travel corridors in major cities. An efficient public transport option can help reduce this congestion problem and can provide affordable travel option for socially vulnerable sections of the society. Construction of BRT is one of such public transport option that can help reducing congestion. In Pakistan, the first of this kind of project was started in Lahore, and very soon after the BRT Lahore, the Rawalpindi-Islamabad BRT was started. Then Multan and now recently a BRT was constructed in Peshawar to improve travel conditions of the city. So, it shows a very rapid trend of implementation of BRT 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 BRT projects. In this study, the impact of BRT on travel condition on adjacent major corridor is being measured. That includes vehicle operating cost (VOC), fuel emissions and level of service (LOS) of the road network. This study will be helpful for the government and other departments or organization involved in planning, constructing and managing public transit projects to better understand the development and post-operationalized utility of such projects.

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 BRT implementation, operation, monitoring evaluation and impact.
- Formation of research performance indicators.
- Collection of secondary data from the concerned departments and authorities.
- Collection of primary data from site.
- Sorting and interpretation of data for both the scenarios i.e. with and without BRT.
- Preliminary findings for both the scenarios i.e. with and without BRT.
- Analyzing the data for each of the performance indicator.
- Extraction of results from the analyzed data.
- Conclusion of study and provision of recommendations.

1.6 ORGANIZATION OF THESIS REPORT

This thesis contains a total of Five chapters, a brief introduction is given as follows.

- Chapter 1.

  This 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.

- Chapter 2.

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

- Chapter 3.

  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, and data collection processes and complete procedures for the analysis of the collected data.

- Chapter 4.

  Chapter four is the analysis and results chapter, which provides the detailed analysis of each of the performance indicators. The key performance indicators include vehicle operating cost (VOC), fuel emissions and level of service (LOS) for both the scenarios i.e. with and without BRT. Based on the analyzed data, results for each indicator have been extracted and discussed.

- Chapter 5.

  Chapter five of the thesis report concludes the overall work carried out in the research process. It includes conclusions and provides recommendations 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.

CHAPTER 2: LITERATURE REVIEW

2.1 GENERAL

In Pakistan, the idea of a bus rapid transit system (BRTS) is relatively new. The first initiative of this sort was started in Lahore, the provincial capital of Punjab in February 2013 with the objective of providing a quality bus service to the residents of Lahore. Istanbul, Turkey's BRT served as a model for the construction of the Lahore BRT. The public responded positively to this initiative, which is now operating successfully. It has a 27-kilometer corridor that runs from Gajumata to Shahdara and serves 180,000 to 220,000 daily riders. It was followed by the Rawalpindi-Islamabad Metro bus service, that was launched in June 2015. It is a 22.5 km long corridor with an average daily ridership of 138,000, that starts from Saddar, Rawalpindi and ends towards Pak Secretariat, Islamabad. The third BRT service in Pakistan, the Multan Metro Bus Service, began operations in January 2017. It is a dedicated 18 km-long corridor that runs from Bahauddin Zikriya University to Kumharanwala Chowk and provides daily service to 97,000 people. After BRT Multan, a BRT project was launched for Peshawar city as well. Its construction began in 2017 and it became operational in 2020. This reveals a countrywide trend of the number of BRT projects being implemented very quickly. Therefore, it is crucial to assess and evaluate such projects to determine whether they are legitimate and fulfilling the objectives for which they were initiated. As was already mentioned, BRT is a new idea in Pakistan; there isn't any literature specifically on the evaluation, assessment and impact of such projects. Checking the viability and applicability of BRT projects hasn't been done very much at all. Therefore, this research study offers basis and an assessment tool in this regard.

Anything that is published as a book, a research paper, an article, a journal, a magazine, or a newspaper is considered literature. An extensive and comprehensive explanation and summary of all the information found in the literature on a particular subject is known as a literature review. Literature review is one the most important and initial step while conducting any research study. It is the method through which a large topic can be summarized into a more focused one, as well as the method and framework for carrying out a research study on this topic can be carried out while reading the literature.

The literature review chapter of this thesis report examines recent and earlier works and research on the evaluation, assessment and impact of public transportation systems following their implementation, with a focus on bus rapid transit systems. The chapter's discussion also touches on various research methodologies that were utilized to measure the effects of BRT on adjacent corridors. The analysis takes into account the operating cost of vehicles, safety impacts, fuel emissions and level of service.

2.2 IMPORTANT CONCEPTS AND TERMINOLOGIES

Some of the key ideas and technical terms employed in the research study have been briefly addressed in this section. The classification and explanation of terminology has been done in accordance with important performance indicators.

2.2.1 FLOW

Traffic flow or traffic volume refers to the total number of vehicles that pass through a particular point, lane, or section of a road at any given time (HCM, 2010). Typically, it is expressed in terms of vehicles per hour or vehicles per day. The measurements are made by counting the number of passing cars at a particular location over a predetermined period of time.

2.2.2 DENSITY

According to the highway capacity manual, density is the quantity of vehicles that occupy a specific length of a lane or segment of road at any given time (HCM, 2010). The usual unit of density is vehicles per kilometer. It gauges how closely together cars are moving in a traffic flow, which ultimately affects how easily a driver can navigate the flow while driving.

From the standpoint of users and system operators, traffic density is a key macroscopic characteristic of traffic flow and is used to evaluate traffic performance (Al-Sobky & Mousa, 2016). Since density measures how close other vehicles are to one another, which affects drivers' freedom of movement and psychological comfort, it is also a crucial indicator of the efficiency of traffic flow (Roess, 2004). For these reasons, the Highway Capacity Manual used the traffic density as the primary level of service (LOS) indicator in situations where there was an uninterrupted flow of traffic.

2.2.3 CAPACITY

The maximum sustainable hourly flow rate at which a specific number of vehicles can be expected to pass through a point, a lane, or a roadway segment at a specific time under normal environmental, traffic, and control conditions is known as a facility's or a network's capacity (HCM, 2010).

Under ideal traffic conditions, when there is no bottleneck and queueing, at a given segment of the road or a facility, the maximum number of vehicles can maneuver through the facility at a certain period. It is a significant parameter that gives insight into the facility's operational characteristics. However, the capacity of the road can be affected by a wide range of variables, including accidents (Lu et al., 2020), road geometry, environmental conditions, and more.

2.2.4 VOLUME MEASUREMENTS

volumes are varying function that keeps changing for every period. Therefor it is necessary to keep track of the volume changes occurring in the facility. Measuring traffic volumes is necessary to maintain the level of service offered to users, and doing so aids in keeping track of changes in the traffic stream. This aids in identifying some important characteristics, such as peak hour volumes, which aid in project design. Therefore, measurements of traffic volume aid in not only managing traffic flow but also inventing new and improved structural and policy improvisations.

It can also cover a range of time frames, such as 1hr, 4hr, 12hr, 16hr, and so forth. At different scales, traffic volume can be measured at both nodes (such as intersections) and the network base (e.g., area, city, region) (Macioszek & Kurek, 2021). Various techniques can be used to measure traffic volume (Jacyna et al., 2014):

- **Manual measurement methods**: This is the simplest and most widely used method, which entails manually recording each vehicle that passes the road section during a given period of time on forms or with mechanical or electronic tools.
- **Automatic measurement methods:** Consisting of photoelectric sensors, radar sensors, video detection, and counters activated by detection loops for the automatic identification and registration of traffic participants as they pass. Field research

frequently makes use of video detection. Modern traffic monitoring systems are often part of the area-based Intelligent Transport Systems (ITS). Additionally, they can group vehicles and gather data on their speeds, distances and the time gaps between one another.

Many developed nations now have automated traffic counters, tolling systems, and other technologies installed on major roads. These technologies can provide consistent and reliable information on daily road traffic volume (Cieśla et al., 2020).

2.2.5 SPEED

In transportation engineering – the distance(s) that a vehicle travels in a given amount of time (t) is referred to as speed. The most important consideration in geometric design is speed because roads are constructed to accommodate specific speeds and speed affects how much a highway project will cost. The cost of that project will increase in direct proportion to the amount of speed you are offering the riders.

Speed is not consistent. The location of the vehicle, the layout of the road, the driver's intent when operating the vehicle, the time of day they are riding, the level of traffic in that area, the weather, visibility on the road, etc., are just a few of the many variables that affect a vehicle's speed. Because all these factors are varying and are very complex to tackle, the speed is constantly changing, even in very brief periods of time. Following are some types of speed.

- **Running Speed:** It refers to the vehicle's average speed during a continuous trip during which the vehicle hasn't stopped. The car might have slowed down, but it hasn't stopped. Posted speed is the speed that is indicated on the signs that are placed along the road. Design speed is the speed for which the road was planned. The speed on which most vehicles are travelling on a given road.

- **Journey Speed or Travelling Speed:** The total average speed of the vehicle is calculated by dividing the distance between two stations by the time it takes, including any stops, plus the distance travelled. As a result, it takes into account both the speed of nonstop travel and the duration of any number of stops.

Speed is a crucial factor in supply chain management. For example, if you need to supply a specific fresh fruit that will go bad after a certain amount of time, you must take into account all the important factors that have an impact on the speed. In the same way, all speeds are taken into account and researched in traffic engineering.

- **Instantaneous – Time Mean or Spot Speed:** It is the speed that has been determined or measured at a particular time. It can be determined, for instance, by a radar inspection system. It is used to research traffic's speed patterns. Additionally, the percentile speed is checked using it. The operating speed of the road is determined by using the percentile speed.

How to Calculate the Percentile Speed?

First, the top 100 sample vehicle's top speeds are noted and listed in ascending order. The 85th percentile of the governing speed is then calculated, and the resulting value is used to determine the highway's operating speed. In this case, the 85th percentile would indicate that only 15 out of 100 vehicles have a speed higher than the specified speed, and 85 out of 100 vehicles have a speed lower than the specified speed.

You must take note of a speed in the 85 percentile such that only 15% of cars have a speed greater than this and 85% of cars have a speed lower than this particular speed. As a result, this particular speed is used or taken into account as the operating speed of the roadway.

- **Space Mean Speed:** It is the average speed of the vehicle, determined at specific length of the highway section. This speed is determined by marking two sections on the road firstly, and then a specific vehicle tends to crosses that section. Just as it crosses it, the stopwatch is set on and when it leaves the section, timer on stopwatch is turned off. That calculated speed will be known as space mean speed.

- **Design Speed:** It is the speed for which the highway is designed, taking into account all design factors such as lane width, median, shoulders, weather, visibility, volume of traffic, type of traffic, number of lanes, etc.

2.2.6 FREE FLOW SPEED (FFS)

The HCM defines free flow speed (FFS) as the "average speed of vehicles on a given segment, measured under low-volume conditions, when drivers are free to travel at their desired speed and are not restricted by the presence of other vehicles or downstream traffic control devices."

the estimation of LOS and capacity for uninterrupted highways facilities, FFS is a crucial parameter. Although field measurements are the preferred method for determining FFS, thus the HCM 2010 offers models for its estimation in the absence of field data. When the HCM 2010 is modified for use in nations outside of North America, such models need to be recalibrated for the local circumstances (Andrade et al., 2016).

The HCM offers two techniques for calculating the free-flow speed (FFS) of a roadway. These are (1) estimation based on roadway characteristics, and (2) estimation based on the posted speed limit, in that order of preference.

- **Estimation Based on Roadway Characteristics:**

From the (HCM, 2010), the following equations are used to estimate FFS based on roadway characteristics.

$$FFS = BFFS - \alpha_{LW} - \beta_{RLC} - 3.22 \times RD^{0.84} \tag{1}$$

&

$$FFS = BFFS - \alpha_{LW} - \beta_{RLC} - \alpha_{M} - \beta_{A} \tag{2}$$

Where:

FFS: free flow speed (mph)

BFFS: base free flow speed (mph)

$\alpha_{LW:}$ lane width adjustment (mph) = 0.0 for lane widths under 12 feet, 1.9 for lane widths between 12 and 11 feet, and 6.6 for lane widths between 11 and 10 feet.

$B_{LC:}$ right-side lateral clearance adjustment (mph)

RD: the average number of on- and off-ramps per mile in a stretch that runs 3 miles upstream and downstream from the segment's midpoint is the total ramp density (ramps/mi).

β_{RLC}: total lateral clearance adjustment (mph)

α_M: undivided highways receive an adjustment for median type (mph) of 1.6, while divided highways and highways with a two-way left-turn lane receive an adjustment of 0.0: and

β_A: adjustment for access point density (mph) = 0.25 × the average number of access points per mile on the right side of the highway, counting only those accesses that influence traffic flow

Table 2-1 (Right Side Lateral Clearance Adjustment Factor βLC Values (mph)

S/No.	**Right Side Lateral Clearance (ft)**	**Lanes in One Direction**			
		2	**3**	**4**	**≥ 5**
1.	≥6	0.0	0.0	0.0	0.0
2.	5	0.6	0.4	0.2	0.1
3.	4	1.2	0.8	0.4	0.2
4.	3	1.8	1.2	0.6	0.3
5.	2	2.4	1.6	0.8	0.4
6.	1	3.0	2.0	1.0	0.5
7.	0	3.6	2.4	1.2	0.6

Table 2-2 Total Lateral Clearance Adjustment Factor βRLC Values (mph)

S/No.	Four Lane Highways		Six Lane Highways	
	TLC (ft)	Reduction in FFS, β_{RLC} (mph)	TLC (ft)	Reduction in FFS, β_{RLC} (mph)
1.	12	0.0	12	0.0
2.	10	0.4	10	0.4
3.	8	0.9	8	0.9
4.	6	1.3	6	1.3
5.	4	1.8	4	1.7
6.	2	3.6	2	2.8
7.	0	5.4	0	3.9

The design speed is assumed to be the base FFS (if available), or the speed limit plus 5 mph or 7 mph (for limits greater than 50 mph) can be used as an estimate. Use the lowest advisory speed as the base FFS if the segment contains one or more horizontal curves with advisory speeds below the posted speed limit.

- **Estimation Based on the Posted Speed Limit:**

In this method, the Free Flow Speed (FFS) of vehicles is calculated by adding 5 mph in the posted speed limit (for level and rolling terrain). However, if the segment contains one or more horizontal curves with an advisory speed less than the speed limit, the lowest advisory speed within the segment plus 5 mph is used as the automobile FFS (Deardoff et al., 2011).

2.2.7 VEHICLE OPERATING COST (VOC)

Vehicle operating costs refer to expenses such as fuel, tires, support, repairs, and mileage-related devaluation costs that change depending on how often a vehicle is used. When evaluating and contrasting the highway improvement options, it is crucial to take vehicle operating costs (VOC) into account. Variations in surface types, paving conditions, roadway geometry, the environment, operation speed, and other factors all affect VOC. The depreciation of the vehicle and crew costs, which can change with the amount of time the vehicle is used, are additional elements of VOC. Overheads and interest charges are the final two parts of VOC. Based on the advantages gained and expenses incurred under different scenarios, highway projects are analyzed to determine whether and how they should be carried out. Travel time and crash reductions are two of the most important advantages of the majority of highway projects. Whereas the third major impact on highway users is the vehicle operating cost (VOC) for trips through the area.

According to (Litman et al., 2009), vehicle costs include the direct client expenses for claiming and using private vehicles. These show the investment proceeds from decreased vehicle ownership and usage. These can be divided into fixed costs (also known as possession or time-based costs, which are unaffected by the amount of miles driven, such as vehicle ownership costs, registration fees, insurance costs, etc.) and variable costs (also known as working, negligible, or incremental costs, which increase with mileage, such as fuel, vehicle repair and maintenance, tyre wear and tear, etc.). Some costs that are typically categorized as fixed, like depreciation and insurance, actually increase with vehicle mileage.

The increase in congestion, an increase in vehicle operating cost (VOC) is shown. The vehicle's speed decreases as a result of the congestion. Increased VOC is another effect of this slower speed. The relationship between vehicle depreciation rate and average vehicle speed as a function of vehicle class was discussed by (Sinha & Labi, 2007b). The rate of depreciation of the vehicle decreases as the vehicle's average speed rises. This relationship has been shown by the below ***Figure 2-1***.

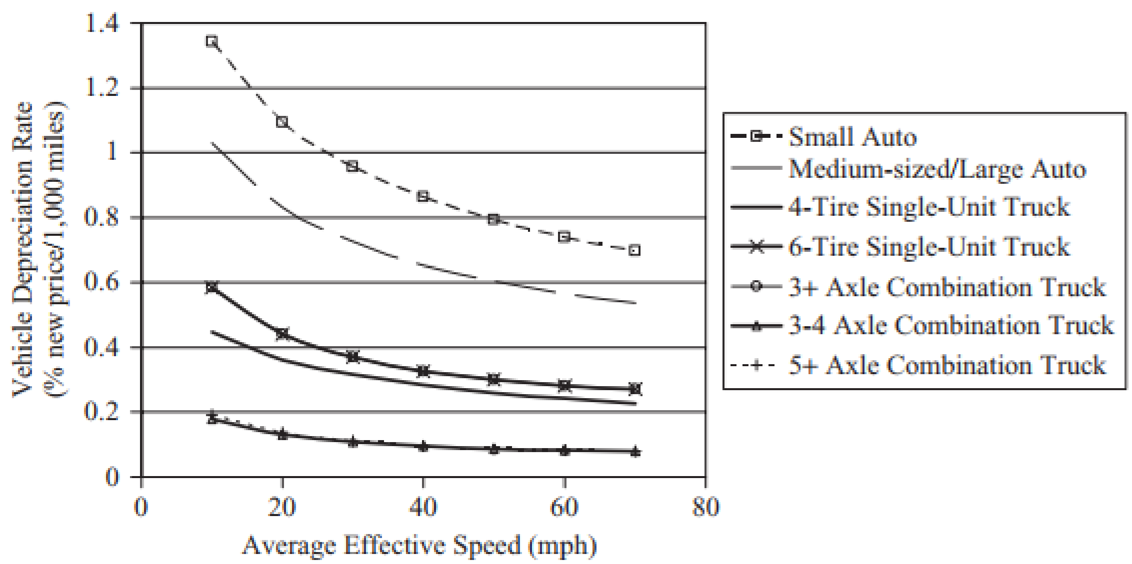

Figure 2-1 Depreciation rate by speed for straight sections from (Hung et al., 2009)

A change to any part of the multimodal framework can affect the VOCs of other parts or different modes for area-wide or corridor-level projects that include it. For instance, a change in the cost of suburban rail service or the placement of a transport rapid transit along a hallway can affect the level of service provided by roadway offices in the same passage because the conversion of some travelers from cars to transit would result in improved interstate level of service due to reduced congestion, which would reduce or eliminate the costs associated with operating vehicles on the highway segment (Sinha & Labi, 2007b).

As was already mentioned, a significant portion of the overall costs associated with travelling are related to VOC. VOC is affected by a variety of factors. The factors that affect the VOCs were briefly discussed by (Sinha & Labi, 2007b) in their book "Transportation Decision Making, Principles of Project Evaluation and Programming" for a clearer and easier understanding. The following ***Figure 2-2*** provides a schematic representation of this.

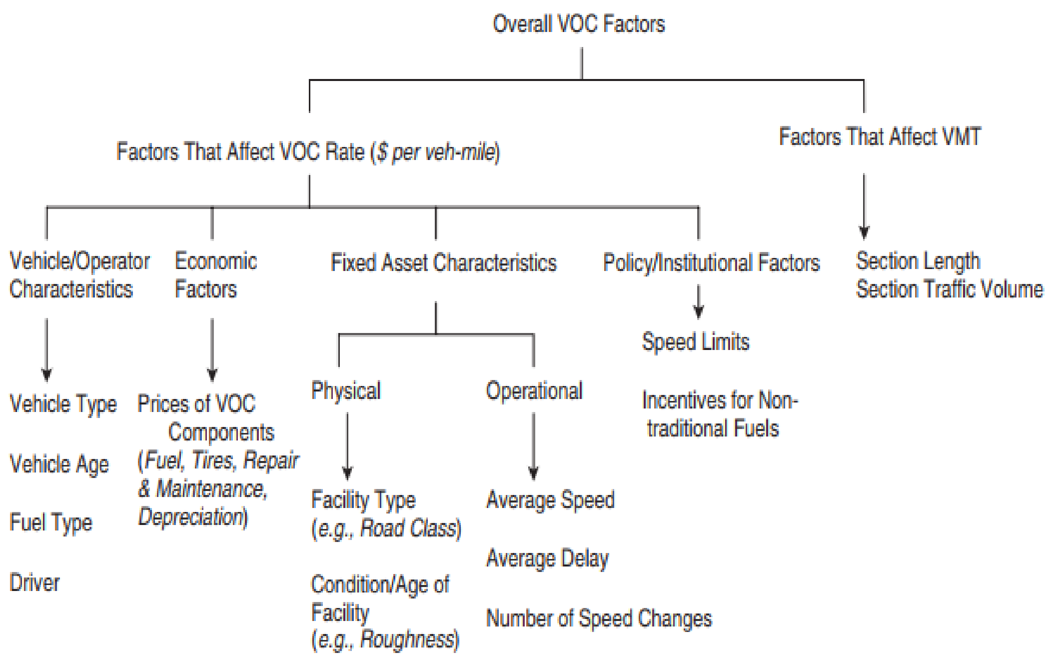

Figure 2-2 Factors that affect highway vehicle operating costs (Sinha & Labi, 2007b)

Hepburn provided a model to bring the vehicle operating cost (VOC) into monetary terms. This urban roadway model takes into account the total of four VOC components, including tire, fuel, vehicle depreciation, and maintenance. The model is particularly useful for evaluating the VOC effects of transportation interventions that typically result in a change in operating speeds or arrangements that change the appropriation of vehicles based on class. The Hepburn model looks like this:

For average travel speeds less than 50 mph, VOC are calculated as follows:

$$VOC\left(in\frac{cents}{mile}\right) = C + \frac{D}{V_S} \tag{3}$$

For average travel speeds 50 mph and over, the model can be approximated as follows:

$$VOC\left(in\frac{cents}{mile}\right) = a_0 + a_1 V_S + a_2 V_S^2 \tag{4}$$

Where:

Vs: Vehicle speed in miles per hour

C, D, a_0, a_1, and a_2: These are the coefficients that are the functions of vehicle class

The values of these coefficients are provided in the **Table 2-3** below

Table 2-3 Hepburn Model Parameters (Sinha & Labi, 2007b)

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

2.2.8 FUEL EMISSIONS

Fuel consumption reduction is thought to be urgently necessary given the current emphasis on energy conservation and environmental protection. According to a 2015 study by the International Energy Agency (IEA), the transportation industry significantly contributes to both the world's energy consumption and greenhouse gas emissions (Zarate, 2015). According to a study by (Nesamani et al., 2007), one of the primary causes of air pollution in a country's major cities is transportation. Over the past few decades, there has been a sharp increase in travel demand, which has led to an increase in vehicle traffic and, consequently, congestion, particularly in major cities. One-third more energy is anticipated to be consumed. The carbon emissions brought on by the use of resources for energy are anticipated to increase by 16% by the year 2040.

Transportation vehicles are major source of creating air pollution. Different transportation vehicles produce different environmentally hazardous emissions. Below **Table 2-4** shows different type of air pollutants emitted from transportation vehicles/sources.

Table 2-4 Air Pollutants from Mobile Transportation Sources (Sinha & Labi, 2007a)

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

The number of pollutants that are emitted by vehicles used for transportation depends on a variety of factors. Such influencing factors were discussed by (Sinha & Labi, 2007a) that include road characteristics, vehicle characteristics, vehicle speed level and speed variation, fuel type, and environmental characteristics such as humidity level, temperature, and altitude, among others. (Sinha & Labi, 2007a) calculated the emissions from the transportation vehicles and has been given as below:

$$Total\ Vehicle\ Emission = Emissions\ per\ vehicle\ mile\ travel * Total\ vehicle\ mile\ travel \quad (5)$$

2.2.8.1 Situation in Pakistan

Pakistan is ranked 135th out of the nations that produce greenhouse gas emissions. This accounts for up to o.8% of the total (Khan & Siddiqui, 2017). The amount of Carbon Dioxide (CO_2) and Carbon Monoxide (CO) that vehicles in Pakistan produce is more than 20 times that of non-methane hydrocarbons (NMHCs) and 3.5 times that of Sulphur dioxide (SO_2) that vehicles in the United States produce (Liu et al., 2014). The 12th-ranked vulnerability of Pakistan to climatic change may be the cause, which has a negative impact on Pakistan's economy. In addition, the cost of environmental issues is roughly equal to 6% of GDP, or 365 billion rupees, for Pakistan's economy annually. According to a World Bank study from 1960 to 2013, Pakistan's CO_2 emissions were 68608.28 kilo tones on average, ranging from 14154.62 kilo tones in 1960 to 163060.48 kilo tones in 2012.

Ozone, nitrogen compounds, Sulphur dioxide, and atmospheric particles are the commonly used air quality indicators. In 2006, the Pakistan Environmental Agency and the Japan International Cooperation Agency monitored NO_2 levels in five important Pakistani cities. After sampling from 42 sites, a 2008 study for Rawalpindi found that the average NO_2 concentrations were 27.46 ± 0.32 ppb. According to the study, at all the sampling points' NO_2 values were higher than the annual limit value established by the WHO.

Table 2-5 Ambient Air Quality Levels (Pakistan) (mg/m3) (Source: WHO)

Name of City	Type of Pollutant					
	PM_{10}	Pb	CO	NO_X	O_3	SO_2
Karachi	192	5	NA	1035	0	97
Lahore	306	2.5	2721	51	65	58
Rawalpindi and Islamabad	149	2.3	NA	105	NA	NA
Peshawar	NA	3	834	53	30	1
Faisalabad	361	2	2520	45	51	12
Multan	519	1.6	1890	38	43	6.6
Gujranwala	281	2.4	3179	46	59	6.8
Hyderabad	NA	1.6	NA	NA	NA	NA
Quetta	138	0.7	NA	NA	NA	NA
World Health Organization	70	0.5	10000	150	100	50

2.2.8.2 Effect of Vehicular Emission

Vehicle emissions have consistently been linked to significant burdens of disease in developing nations. Children and the elderly are especially at risk from vehicle emissions. Reduced lung function as a result of respiratory illnesses like pneumonia, asthma, and bronchitis is just one of the harmful health effects of particulate matter. According to estimates, the transport industry contributes roughly 14.9% of the annual global particulate matter. According to studies done for Lahore, the percentages are 14.7 percent and 26 percent, respectively. In Pakistan, air pollution causes 6.4 million hospital admissions and illnesses each year, as well as about 2500 infant deaths (Bhattarai & Conway, 2021).

1. **Impacts of Carbon Monoxide on Health and Environment:**

Carbon Monoxide (CO) may be a standout among the pollutants that may combine with sunlight to produce ground-level ozone, or "Smog," which is especially problematic during the summer's high temperatures. The Clean Air Act (CAA) classifies carbon dioxide, as a colorless, odorless, and highly toxic gas, that is dangerous for both the environment and human health. The primary cause of the chemical carbon monoxide (CO), which is listed as a special health hazard, is the incomplete combustion of vehicle fuel. Carbon monoxide (CO) inhalation may result in headaches, lightheadedness, and exhaustion. Sleepiness, memory problems, mental confusion, and vision loss can also result from increased exposure.

2. **Impacts of Sulphur Dioxide on Environment:**

Acid rain is brought on by Sulphur dioxide emissions. Acid rains harm forests, vegetation, and our eco system when they fall. The high light scattering ability of Sulphur dioxide and the haze it produces in the environment have an impact on visibility as well.

3. **Impacts of Sulphur Dioxide on Health:**

When coal, fuel, etc. are burned, Sulphur dioxide (SO_2), a colorless gas with a sharp and unpleasant odor, is released into the atmosphere. When SO_2 is dissolved in the air, significant amounts of pollutants that are harmful to human health are produced. Inhaling SO2 at levels of 8 to 12 ppm for a few minutes can irritate the throat, while 20 ppm will immediately cause coughing and eye irritation (Zhang & Srinivasan, 2020). Sulfur dioxide is more harmful to people who have heart, lung, or asthma problems, according to the World Health Organization.

4. **Impacts of Nitrogen Oxides on Environment:**

The main sources of nitrogen oxide production are motor vehicles, the burning of coal, oil, and other fuel-burning processes. Nitrogen oxides are composed of nitrogen and oxygen. Smog, acid rain, and ozone are produced when sunlight and nitrogen oxides (NOx) react, followed by a reaction with volatile organic compounds (VOC) (Dutta & Singh, 2021).

5. **Impacts of Nitrogen Oxides on Health:**

Human health is also harmed by nitrogen oxides; the safe exposure limit for nitrogen dioxide (NO_2) is 5 ppm with a time limitation of up to 15 minutes, which should not exceed more than four times per day, and the gap between the exposures should be 1 hour. Nitrogen Dioxide (NO2) causes lung tissue damage when it is inhaled directly, and its acute health effects include eye irritation, throat infection, lung infection, and the induction of asthma in people who already have the condition (Donohoe & Keegan, 2008).

2.2.9 LEVEL OF SERVICE (LOS)

According to the Highway Capacity Manual (HCM 2000), capacity is "the maximum hourly rate at which persons or vehicles can reasonably be expected to traverse a point or a uniform segment of a lane or roadway during a given time period under existing roadway, traffic, and control conditions". Roadway condition (road geometry), traffic condition (traffic mix and traffic stream characteristics), and control condition (signs and signals) all affect the capacity of a highway (Makhloga, 2022).

Delay is a crucial performance indicator for any facility because, despite a facility's capacity remaining constant, traffic flow will always vary for different periods of time, leading to fluctuating delay. Delay is defined as an excessive or unforeseen amount of travel time (Knapen et al., 2014). Three factors - speed or travel time, density, and delay are typically considered when determining the level of service provided by any facility. These are the most significant factors that have an impact on a facility's LOS. The presence of other vehicles in the stream is indicated by density.

Level of Service is defined as "a quality measure describing operational conditions within a traffic stream, generally in terms of such service measures as speed and travel time, freedom of movement, traffic interruptions, comfort and convenience" in the Highway Capacity Manual (Pandey et al., 2022). According to (HCM, 2000), there are six LOS levels, ranging from LOS-A to LOS-F, with LOS-A designating the best traffic operating condition and LOS-F the worst (Vrbanić et al., 2022). The LOS has been defined in HCM (2000) in terms of specific Measures of Effectiveness (MOE) for various types of facilities (Sourava Mohapatra & Pratim Dey, 2021). It has been demonstrated in the **Table 2-6** below

Table 2-6 Measure of Effectiveness defining LOS

S/No.	**TYPE OF FLOW**	**TYPE OF FACILITY**	**MEASURE OF EFFECTIVENESS (MOE'S)**
1.	**UNINTERRUPTED FLOW**	Freeways	Density (pc/mi/ln)
2.		Basic Sections	Density (pc/mi/ln)
.3		Weaving Areas	Density (pc/mi/ln)
4.		Ramp Junction	Density (pc/mi/ln)
5.		Multilane Highway	Density (pc/mi/ln)

6.		Two Lane Highway	Average Travel Speed (mph)
7.	**INTERRUPTED FLOW**	Signalized Intersections	Control Delay (sec/veh)
8.		Un-signalized Intersections	Control Delay (sec/veh)
9.		Urban Streets	Average Travel Speed (mph)
10.		Transit	Service Frequency (veh/day)
11.		Pedestrians	Space (ft/ped)
12.		Bicycles	Frequency of Conflicting Events

Certain elements have an impact on a highway segment's LOS. These elements consist of:

- Travel time and vehicle speed.
- Road geometry (Lane width, lateral clearance, median type etc.).
- Interruptions in traffic (Signals).
- Comfort and convenience for the driver.
- freedom to move
- Operating cost

2.2.10 PASSENGER CAR UNITS

There are many different classes of vehicles in a traffic stream, each with unique characteristics like length, width, and the amount of road space they occupy. Vehicles are converted to a single common unit, the passenger car unit (PCU) or passenger car equivalents (PCE's), to account for the no uniformity in their static and dynamic characteristics.

The scale used in transportation engineering to determine the traffic flow rates on a transportation facility is the passenger car unit (PCU), is also referred to as the passenger car equivalent (PCE) (Sivagnanasundaram et al., 2019). PCU is a measurement of how different modes of transportation affect different aspects of transportation, such as headway, speed, etc., in comparison to a reference vehicle, also known as a single unit car. PCU is a collection of values or conversion factors for various vehicles that were obtained through in-depth empirical research. Different departments use different values depending on the homogeneous and heterogeneous traffic conditions that are prevalent in their respective regions (Adnan, 2014).

Passenger Car Unit (or PCE) factors used in this research are the PCU factors provided by (Adnan, 2014) in his study are shown in the **Table 2-7** below,

Table 2-7 PCU factors provided by (Adnan, 2014)

S/No.	**Passenger Car Unit (PCU) Values for Various Vehicle Types**	
	Vehicle Classes	**PCU Factors**
1.	Car/Jeeps/Vans/Taxi	1.00
2.	Motorcycles/Scooters	0.25
3.	Auto Rickshaw	0.50

4.	Pickups	1.50
5.	Mini Buses	2.00
6.	Large Buses	2.50
7.	Trucks and Trailers	3.00

2.2.11 SYNCHRO

Synchro software is developed by Traffic Ware Inc., Synchro is a comprehensive software package for modeling, optimization, managing, and simulating traffic systems. It is used to generate coordinated signals and their timing plans for roadways and arteries etc. It is applied to the analysis of roundabouts, freeway facilities, and intersections with and without signals. Synchro is designed to function according to the Highway Capacity Manual's guidelines. The most recent model, version 10.1, not only includes HCM 2010, but it also incorporates HCM 6th edition for analysis and simulation. The older version of the software only used HCM 2000 for analysis and report generation. It is the most popular software for modelling and simulation for intersections and freeway segments due to its simplicity and capability to conduct analysis based on Highway Capacity Manual. Some of the important features of synchro are stated below:

- Its use and evaluation of effectiveness are simple. It makes it possible for observers to quickly spot traffic trends.
- Additionally, it supports the Highway Capacity Manual's (HCM) methodology for roundabout, intersection, and U-turn.

- It has the ability to measure fuel emissions, which aids in calculating the cost of operating a vehicle.
- The software's interference is easy to use, and it is designed to function even with a small amount of input data.
- Users have access to a wide range of precise effectiveness metrics that were calculated throughout the optimization process.
- Vehicles and pedestrians are micro-simulated and animated by Synchro (Sim Traffic) (Ullah et al., 2021).
- The visual display of Synchro features a variety of diagrams. Users can alter the offsets and delays and watch how those changes affect the delays, stops, and LOS. The best option for their intersection or the entire network can be chosen by users after comparing those options.

It is programmed to determine delays, the volume-to-capacity ratios, the level of service, and intersection capacity utilization. It helps to design and modify intersections. The diagrams angle graph that it shows enables you to adjust the delays and offsets as well as see how they affect LOS and travel delays. Users can contrast these options with the best intersection, route, or overall network. By altering the input value to obtain a different result automatically, it also assists the user in creating plans for the best traffic flow.

2.3 SYNTHESIS OF 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, evaluation and impact of public transportation systems carried out worldwide are as follows:

A review study on the performance evaluation of the BRT Transit System was completed by (Matariya et al., 2017). They claim that BRT offers a flexible, clean, safe, innovative system that is inexpensive, easy to use, and has high mobility that can enhance the quality of service in urban areas. He conducted research on the performance assessment of BRT in India using a variety of on-board surveys, including those measuring delay time, public opinion, travel time, and passenger frequency. They investigated the Janmarg, Ahmadabad BRTS, choosing 5 corridors to study for its environmental, social, and traffic impacts. They found that the implementation of BRT increases average speed, reduces congestion, and decreases the composition of pollutants along corridors.

Bocarejo et al., (2012) analyzed an impact of bus rapid transit systems BRTS on road safety in Bogota, Colombia. Over the past ten years, Bogotá, Colombia, has gradually incorporated the high-capacity TransMilenio BRT system in key corridors. The main goal was to significantly improve the availability of public transportation, particularly in terms of capacity and speed. However, the impact on traffic safety has been significant. The effects of implementing these BRT corridors on traffic safety were evaluated by comparing the before-and-after scenarios. Data was analyzed with GIS techniques. The results suggested that the number of accidents reduced. It was also observed on roads that the speed went up because of the elimination of traffic lights, the widening of space for private cars, and the general improvement of road surface.

(Flynn et al., 2011) conducted an evaluation of Los Angeles metro orange line BRT service. The evaluation report included a synopsis of the project that covered its historical context, a profile of its various components, cost, planning and design, project implementation, and operational tools and techniques, among other things. Additionally, the authors developed multiple performance parameters during the evaluation process to evaluate and assess the entire BRT system. Travel time, dependability, capacity, safety, and security were among these criteria. Survey data on user perception and satisfaction, as well as project image and identity, were also examined. The evaluation was concluded with an overall assessment of the project's benefits, including the assessment of ridership, the environmental quality, the financial appropriateness, and the overall success of the project in achieving its goals.

(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.

a post implementation evaluation of TransMilenio 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.

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, 2013) 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.

A notable fact was that the operation of BRT not only provided significantly faster operating speeds for the bus service, but also improved the Travel Speed of the general traffic that runs parallel to the exclusive busway. 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.

According to (Newnam, n.d.), 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.

(Salem et al., 2006) worked on analyzing the implementation of new bus rapid transit (BRT) in USA. Morning peak time from 7.30 am to 8.30 am was considered. CORSIM simulation model was used to get the required Measures of Efficiencies and

Benefit/Cost analysis was done by using the equations of operating costs, maintenance costs, transit user costs and highway user costs. It was determined that BRT is more useful for present and future scenarios.

(Bel & Holst, 2018) worked on the evaluation of the impact of bus rapid transit on air pollution in Mexico city. It was introduced in an attempt to reduce congestion, increase city transport efficiency and cut air polluting emissions. The air pollutants considered were carbon monoxide (CO), nitrogen oxides (NO_X), particulate matter of less than 10 μm (PM_{10}) and sulfur dioxide (SO_2). Results showed a significant reduction in the concentrations of all the air pollutants, except sulfur dioxide SO_2.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 GENERAL

Traffic congestion is a major urban transport problem. Efficient public transport (PT) can be one of the potential solutions to the problem of urban road traffic congestion. 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 etc. Public transport systems can carry a significant number of trips during congested hours, improving overall transportation capacity, and can release the burden of excess demand on congested road networks. 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 impact of bus rapid transit (BRT) of Peshawar on travel conditions on adjacent major corridor. The overall research framework is shown below

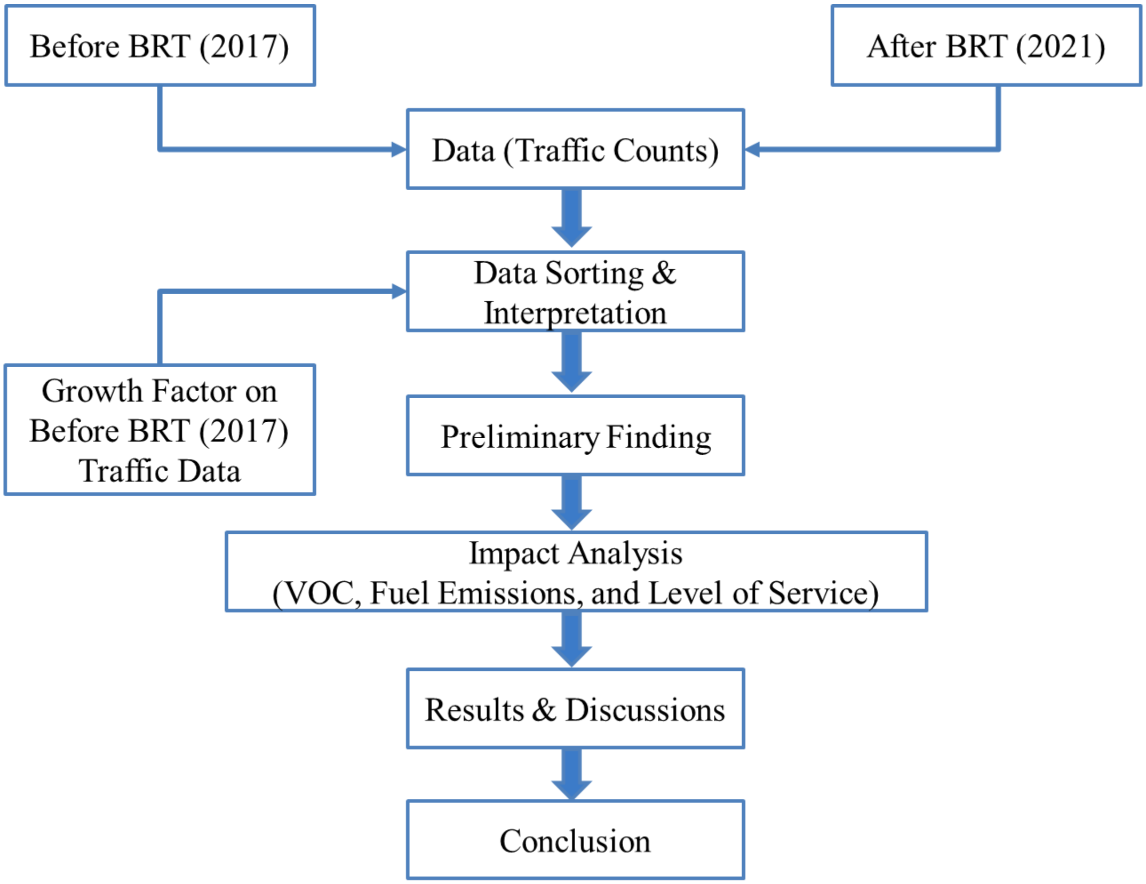

Figure 3-1 Overall Research Framework

3.2 STUDY AREA DESCRIPTION

Peshawar is the capital of Pakistani province of Khyber Pakhtunkhwa. It's the largest city of Khyber Pakhtunkhwa (*Census-2017 - Detailed Tables | Pakistan Bureau of Statistics*, n.d.) and its population has doubled since 1998, when the last census was conducted. It is the sixth-largest city in Pakistan (*Block Wise Provisional Summary Results of 6th Population & Housing Census-2017 [As on January 03, 2018] | Pakistan Bureau of Statistics*, n.d.). The Peshawar metropolitan area is the sixth largest metropolitan area of the country. Peshawar has an annual growth rate of 3.99%, which is the highest amongst all the divisions of Khyber Pakhtunkhwa. It is situated in the broad valley of Peshawar east of the historic Khyber Pass, close to the border with Afghanistan.

Grand Trunk Road and University Road served as a major arterial of Peshawar, covering all day to day activities of Peshawar. Public transport system was not fulfilling the demand of city with less number of buses with low capacity and high travel time, therefore, the provincial government of Khyber Pakhtunkhwa in 2013 put forward an idea of Rapid Bus Transit System for Peshawar City to cater the need of public transport of city named as "TransPeshawar".

The total length of University road is 7.2km (4.5 miles). Out of which a section of 2.2 km (1.367 miles) of university road has been selected for analysis. Service road was dismantled in order to accommodate BRT's corridor on university road. **Figure 3-2** shows a section of 2.2 km (1.365 miles) of university road.

Figure 3-2 A 2.2 km section of university road

3.3 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.

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.

The data for the research study of Impact of BRT on travel conditions on adjacent major corridor was collected from two main sources; i.e. Primary and secondary sources.

3.3.1 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. For collection of primary data for this research study manual traffic count, average spot speed and time travel data were collected in the field.

Manual Traffic Count After BRT

Manual traffic count method was opted for the collection of primary data in this study. Current traffic counts were collected for the period of 24 hours. Having an interval of 15 minutes each. Traffic was counted for both the directions. Traffic counts were collected from the help of CCTV cameras that are installed on university road, alongside the BRT corridor. These cameras are operated by TransPeshawar. Cameras between station number 25 and station number 26 were used for data collection.

Primary data collected was used for vehicle operating cost (VOC) analysis, for finding the fuel emissions and level of service of the road network along BRT for the current scenario i.e. with BRT. **Figure 3-3** shows traffic flow direction on map.

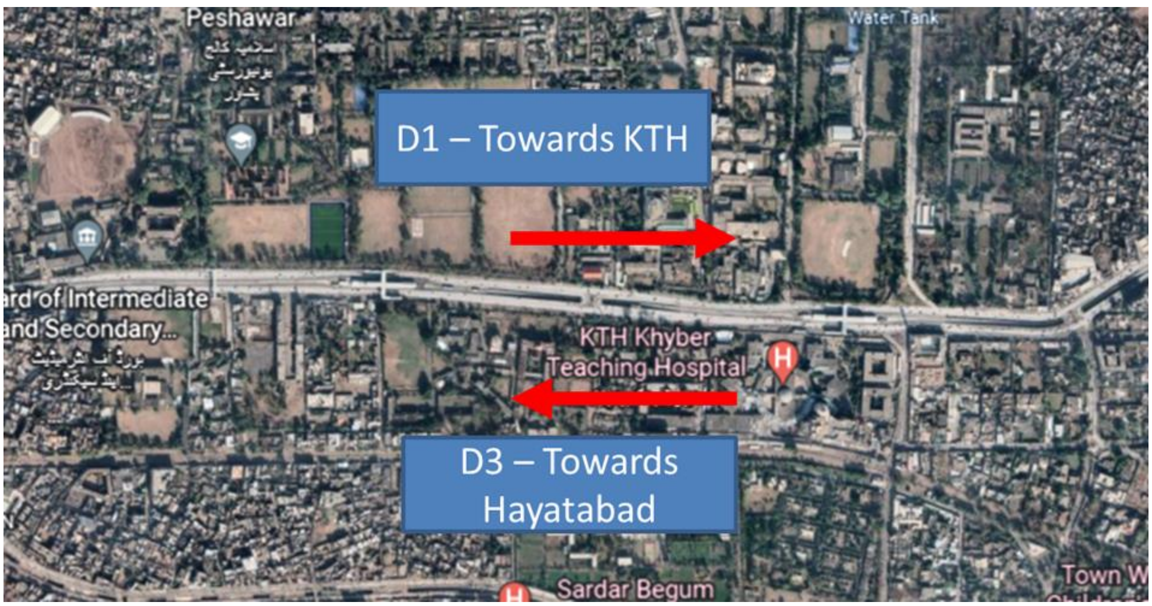

Figure 3-3 Traffic Flow Direction

3.3.2 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 Mott Macdonald (Pvt) Ltd. The data collected or obtained from this organization included pre BRT traffic count data in 2017. The obtained data were brought into 2021 by multiplying the growth factor with 2% growth rate. After that it was analyzed for finding the vehicle operating cost (VOC), fuel emissions and level of service of the adjacent arterial road to the BRT Peshawar.

3.3.3 BPR Function

There are several techniques for estimating travel times, including the COMSIS Corporation method, in-person field measurements, and the Bureau of Public Roads (BPR) function of the Highway Capacity Manual. In this study Travel time delay is estimated using BPR function of Highway. BPR function was used to calculate travel time and then speed for both the scenarios i.e. with and without BRT. So expression for "T" can be written as:

$$T = T_o \left[1 + a \left(\frac{V}{C} \right)^b \right] \tag{6}$$

Where:

T: link travel time (hr)

$T_{o:}$ link travel time at free flow link speed (hr)

a and b: BPR parameters

3.4 DATA SORTING & INTERPRETATION

Any process that involves putting the data in a meaningful order to make it simpler to comprehend, analyze, or visualize is considered data sorting. Sorting is a common technique used to visualize data in a way that makes it simpler to understand the story the data is telling when working with research data. Sorting can be carried out using raw data (across all records) or aggregate data (in a table, chart, or some other aggregated or summarized output).

The traffic counts that were provided to us by Mott Mcdonald (Pvt) Ltd were at an interval of 15 minutes each. From that an hourly volume was find out first. From the help of which we were able to compute the peak hour factor (PHF) values. After that all the traffic counts of 2017 were converted into 2021 by using growth rate of 2%. Which made a scenario of 2021 without BRT. Besides that, we converted all the mixed traffic into a single category i.e. passenger car equivalent (PCE) by multiplying the PCU factors with each class of vehicle. Passenger Car Unit (or PCE) factors used in this research are the PCU factors provided by (Adnan, 2014) in his study.

3.5 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 three key parameters, so every parameter had a different method of analysis. The softwares used in the analysis framework included Microsoft (MS) Excel and

Synchro 11. 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.

Synchro 11 software was used to analyze the fuel emissions produced by vehicles that use the road network for both the scenarios i.e. before and after BRT. Synchro 11 is a traffic analysis software and was incorporated to analyze the fuel emissions that include hydrocarbon (HC), carbon monoxide (CO) and oxides of Nitrogen (NOx) produced by vehicles before the implementation of BRT and after the implementation and operations of BRT Peshawar. University road section of the BRT was chosen to analyze the fuel emissions produced by vehicles. The methodology adopted was first to find the fuel emissions produced by vehicles for pre-BRT scenario, then to find the fuel emissions for post-BRT scenario. The comparison of pre and post BRT implementation gave the assessed situation of traffic. Synchro 11 requires the data of peak hour traffic volume, PHF, and road geometry characteristics.

CHAPTER 4: ANALYSIS & RESULTS

4.1 BACKGROUND

Rapid transit system is becoming more ubiquitous with time in Pakistan as they are being constructed in almost every big city of the country. These projects are usually mega projects that attract a huge amount of public money. Being a third world country, the efficacy of these projects need to be studied and evaluated. In this research study, the impact of Bus Rapid Transit (BRT) Peshawar on travel conditions on adjacent major corridors is evaluated. The procedure is based on different performance measures/parameters/indicators. These performance measures include vehicle operating cost (VOC) of vehicles on adjacent road to BRT, fuel emissions of vehicles on adjacent road to BRT and level of service (LOS) of the network. These analyses are done for two scenarios i.e. without BRT and with BRT for the same year (2021). Before the results of the above mentioned performance measures, some of the preliminary findings are discussed below firstly

4.2 PRELIMINARY FINDINGS

Preliminary findings of this study after the collection of data are

4.2.1 No of Motorcycles and Cars

After the collection of Traffic counts from Mott Macdonald (Pvt) Ltd of before BRT (i.e. in 2017), which was converted into 2021 by applying the growth rate of 2% over the 4 years, it was compared with the traffic counts of after BRT scenario which were collected manually at the same point and same year (i.e. 2021), it was find out that the number of motorcycles have decreased by 1.68% after the implementation of BRT.

Similarly, the number of cars also decreased by 2.15% after the commencement of BRT. The difference in number of motorcycles and cars for before and after BRT scenarios are illustrated in the **Figure 4-1** and **Figure 4-2** below respectively.

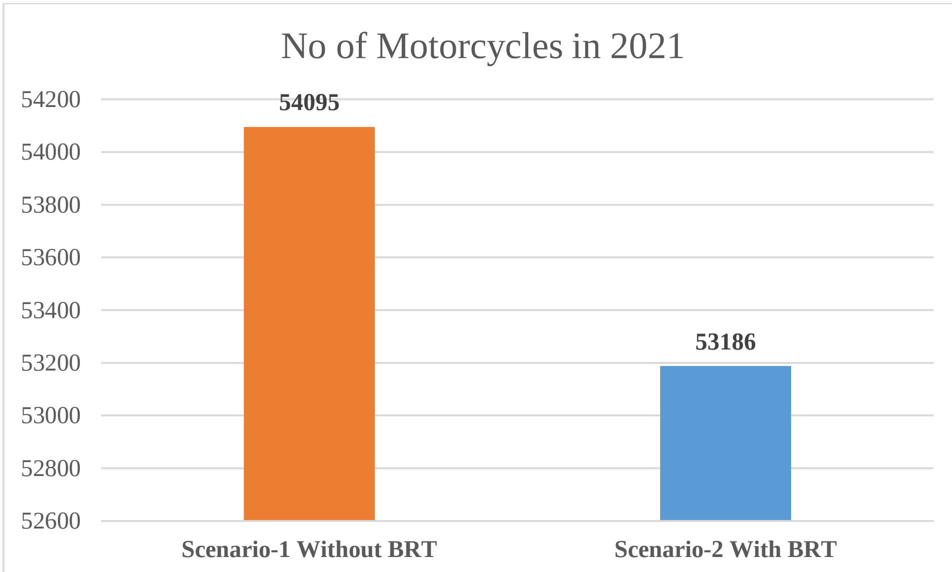

Figure 4-1 Number of Motorcycles in 2021 for both the scenarios

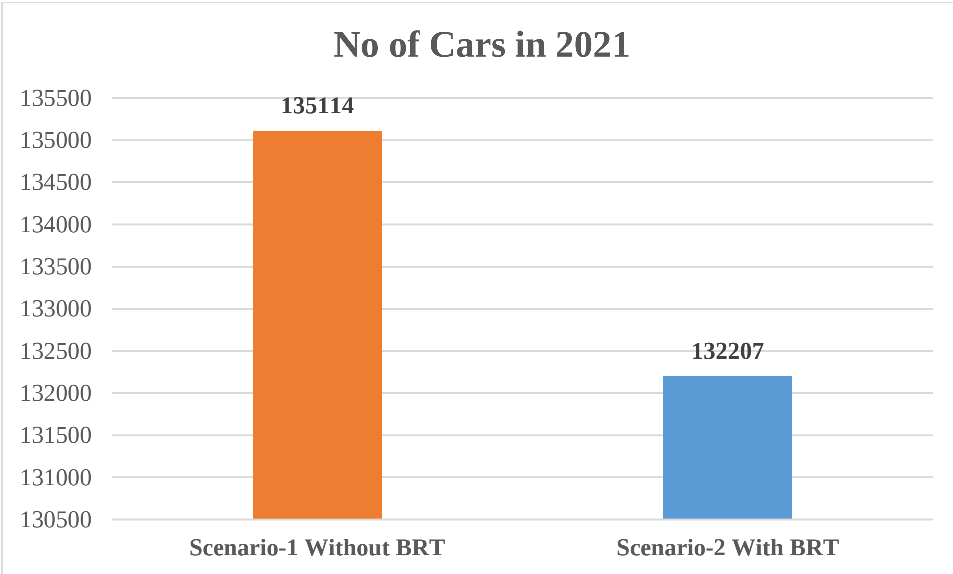

Figure 4-2 Number of Cars in 2021 for both the scenarios

4.2.2 No of Public Transport

After the commencement of BRT, the number of Public transport reduced by a very large percentage i.e. the number of Rickshaws and Qingqis reduced by 86.1% and the number of Suzuki/Wagon/Mazda/Rocket/Large busses decreased by 78.1%. The difference in number of public transport for before and after BRT scenarios are illustrated in the **Figure 4-3** and **Figure 4-4** below.

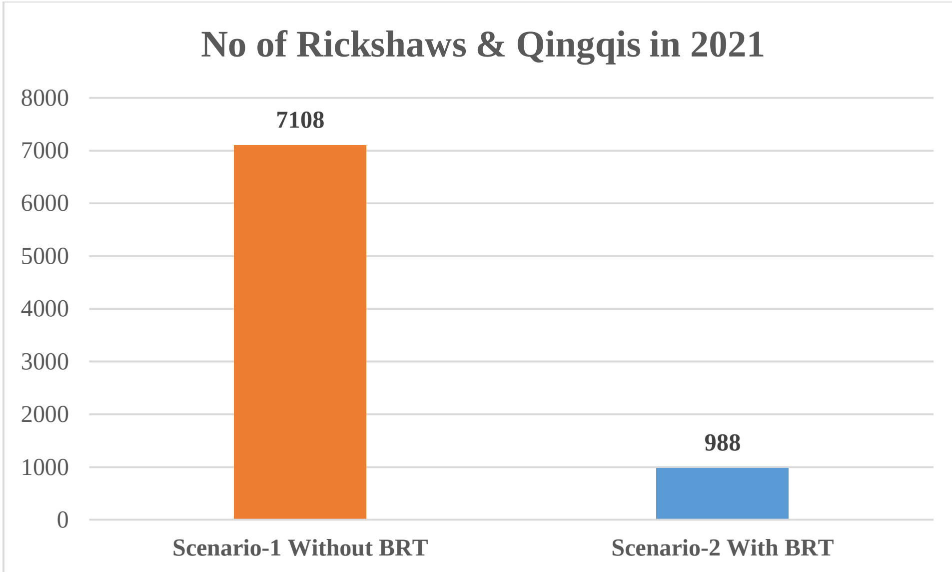

Figure 4-3 No of Rickshaws & Qingqis for both the scenarios

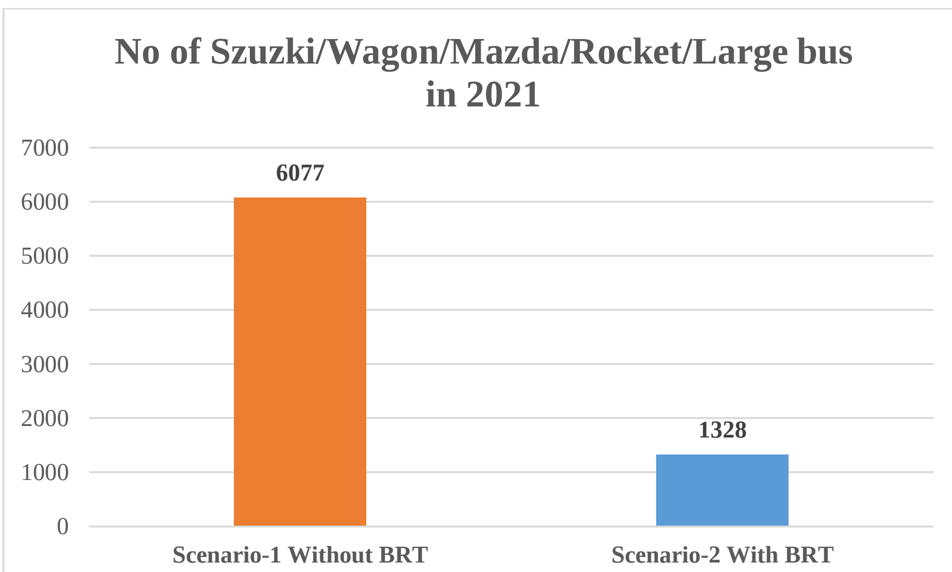

Figure 4-4 No of Suzuki/Wagon/Mazda/Rocket/Large bus in 2021 for both the scenarios

4.2.3 SPEED

Speed calculated with the help of BPR function. Firstly, travel time was calculated for each scenario in both the directions i.e. D-1 and D-3, it was then converted into travel speed by dividing the analysis length by the travel time.

4.2.3.1 Speed without BRT in 2021

The FFS on university road was 65 kmph. And the link distance was taken as 2.2 kilometers. The peak volume at D -1 and D-3 direction was 7255 passenger car units per peak hour (PCU) and 4962 PCU per peak hour. And the value of capacity for a six lane divided urban road was taken as 5700 PCUs/hr for one direction of flow. Whereas, the BPR parameters "a" and "b" have the values of "0.7" and "5.0" respectively. These values are the recommended BPR parameters for arterial roads against the FFS of 65 kmph (National Research Council, 2000). After finding out the travel time for link, speed can be calculated by dividing the link distance by time. The travel time and speed for scenario i.e. without BRT in 2021 at both the directions is shown in the **Table 4-1** below.

Table 4-1 Travel time and Speed without BRT in 2021

S/No.	Direction	Travel Time (hours)	Speed (kph)
1.	D-1 (Towards KTH)	0.112	19.62
2.	D-3 (Towards Hayatabad)	0.045	48.18

4.2.3.2 Speed with BRT in 2021

The peak volume at D -1 and D-3 direction was 6596 passenger car units per peak hour (PCU) and 4293 PCU per peak hour. And the value of capacity for a six lane divided urban road was taken as 5700 PCUs/hr for one direction of flow. Whereas, the BPR parameters "a" and "b" have the values of "0.7" and "5.0" respectively. The travel time and speed calculated for scenario with BRT in 2021 is shown in **Table 4-2** below.

Table 4-2 Travel time and Speed with BRT in 2021

S/No.	Direction	Travel Time (hours)	Speed (kph)
1.	D-1 (Towards KTH)	0.072	30.55
2.	D-3 (Towards Hayatabad)	0.037	58.15

The results of BPR function shows that the scenario which includes BRT has seen an increase in travel speed. The speed has increased from 19.62 kmph to 30.55 kmph i.e. 55% increase in direction-1 towards Khyber Teaching Hospital on University road. Similarly, the speed has increased from 48.18 kmph to 58.15 kmph i.e. a 20% increase in direction-3 towards Hayatabad on University road.

4.3 VEHICLE OPERATING COST (VOC)

One of the primary element that people look up to while choosing any mode of transportation is cost. It is common human psychology that they prefer the mode that costs lower provided that the other services are also up to satisfactory level. The costs of a vehicle may be divided into two categories: 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 can get improved, which can ultimately help in the reduction of vehicle operating costs. So, to assess the suitably of BRT Peshawar on the basis of reducing the vehicle operating cost (VOC) on adjacent major corridor to BRT, the VOC impact analysis was carried out. This approach needed traffic counts for two scenarios. The first scenario included traffic counts without BRT. For this the traffic counts of 2017 was brought to that of 2021 by using the growth rate percentage of 2%. And the second scenario included BRT for the same year. The traffic data on University road after the BRT implementation was counted from the surveillance cameras, that are installed alongside the BRT corridor. It comes under the jurisdiction of Trans-Peshawar. That traffic counts are shown in table as the Appendix-B. The traffic counts before BRT operation were taken from the Mott Macdonald (Pvt) Ltd, who carried out a Manually Classified Count (MCC) for the consultancy services of BRT Peshawar. The MCC was carried out in April 2017. These traffic counts have been shown in table as the Appendix-A.

4.3.1 VOC USING HEPBURN MODEL

After computing the traffic counts and speed, a unit VOC value was to be determined. Hepburn model was used for both the scenarios i.e. before and after BRT. VOC was determined for both the directions i.e. towards KTH and towards Hayatabad.

Since the average speed in both the directions for both the scenarios was less than 50 mph, therefore the following equation was used to find the value of unit VOC.

$$VOC \left(in \frac{cents}{mile} \right) = C + \frac{D}{V_S} \quad (7)$$

Where:

Vs: Vehicle speed in miles per hour

C, D, a_0, a_1, and a_2: These are the coefficients that are the functions of vehicle class

The values of these coefficients are provided in the **Table 4-3** below

Table 4-3 Hepburn Model Parameters (Sinha & Labi, 2007b)

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

4.3.1.1 VOC without BRT Scenario in 2021

The speed for both the direction of scenario without BRT was calculated through BPR function. All the classes of vehicles were brought into a single category i.e. car/jeep/van/taxi by using passenger car equivalency factors that has been used by (Adnan, 2014). For which the coefficients taken were to be (C = 28.5, D = 95.3). The unit VOC value from the Hepburn model was calculated as given below in **Table 4-4**.

Table 4-4 Unit VOC without BRT scenario in 2021

S/No.	Direction	Unit VOC (cents/mile)
1.	Direction-1 (Towards KTH)	36.31
2.	Direction-2 (Towards Hayatabad)	31.68

After the calculation of unit VOC, the vehicle miles travelled (VMT) was to be calculated. It was done by multiplying the traffic counts with the analysis segment length. Product of VMT and unit VOC gave the total VOC value per hour. Similarly, VOC values were calculated for both the directions before the implementation of BRT Peshawar. These calculations have been shown in below **Table 4-5**.

Table 4-5 Total VOC by Hepburn Model of without BRT Scenario in 2021

S/No.	**Without BRT Scenario**	**Length (Miles)**	**Traffic Count (Veh/hr)**	**VMT**	**Speed (mph)**	**Unit VOC (cents/mile)**	**Unit VOC (Rs/mile)**	**Total VOC (Million Rs/hr)**
1.	D-1 (towards KTH)	1.367	7255	9917	12.19	36.31	72.98	0.723
2.	D-3 (towards Hayatabad	1.367	4962	6783	29.94	31.68	63.67	0.431
3.	**TOTAL**							**1.151**

The above **Table 4-5** shows that the VOC in direction-1 was 0.723 million Rs/hr, whereas the VOC in the direction-3 was found out to be 0.431 million Rs/hr. So it was calculated that the total VOC for scenario without BRT in 2021 was 1.151 million Rs/hr.

4.3.1.2 VOC with BRT Scenario in 2021

The speed for both the direction after BRT was also calculated through BPR function. All the classes of vehicles were brought into a single category i.e. car/jeep/van/taxi by using passenger car equivalency factors that has been used by (Adnan, 2014). For which the coefficients taken were to be (C = 28.5, D = 95.3). The unit VOC value from the Hepburn model for the scenario i.e. with BRT in 2021 was calculated as given below.

Table 4-6 Unit VOC with BRT scenario in 2021

S/No.	Direction	Unit VOC (cents/mile)
1.	Direction-1 (Towards KTH)	33.54
2.	Direction-2 (Towards Hayatabad)	31.13

After the calculation of unit VOC of scenario i.e. with BRT in 2021, the vehicle miles travelled (VMT) was to be calculated. It was done by multiplying the traffic counts after BRT with the analysis segment length. Product of VMT and unit VOC gave the total VOC value per hour. These calculations have been shown in below **Table 4-7.**

Table 4-7 Total VOC by Hepburn Model of with BRT Scenario in 2021

S/No.	With BRT Scenario	Length (Miles)	Traffic Count (Veh/hr)	VMT	Speed (mph)	Unit VOC (cents/mile)	Unit VOC (Rs/mile)	Total VOC (Million Rs/hr)
1.	D-1 (towards KTH)	1.367	6596	9016.73	18.98	33.54	67.41	0.607
2.	D-3 (towards Hayatabad	1.367	4293	5868.53	36.14	31.13	62.57	0.367
3.	**TOTAL**							**0.974**

The above **Table 4-7** shows that the VOC in direction-1 was 0.607 million Rs/hr, whereas the VOC in the direction-3 was found to be 0.367 million Rs/hr. So it was calculated that the total VOC for the scenario i.e. with BRT scenario was 0.974 million Rs/hr.

The **Figure 4-5** below shows the VOC values for both the scenarios i.e. before and after BRT. The VOC before BRT was 1.143 (Million Rs/hr), whereas it came down to 1.089 (Million Rs/hr) after the commencement of BRT.

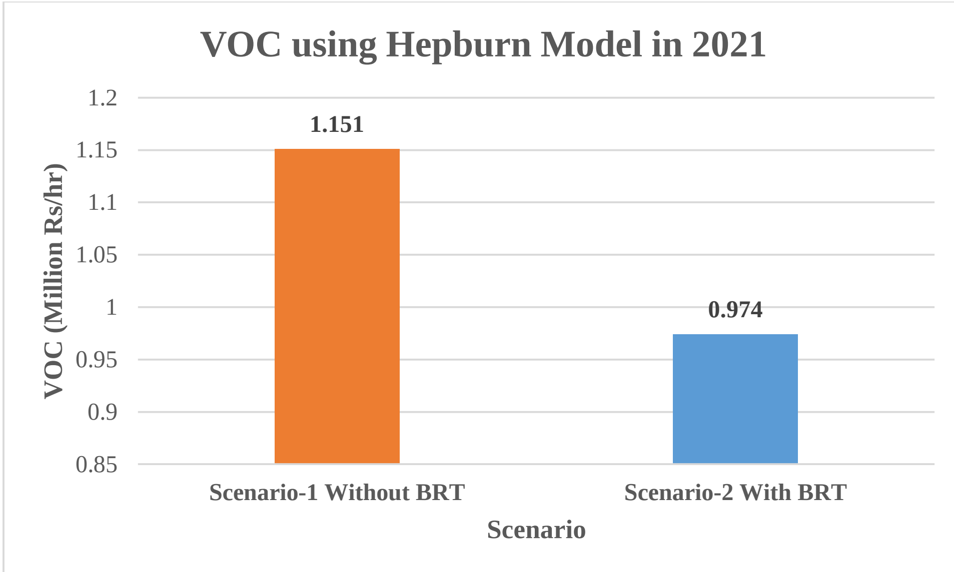

Figure 4-5 VOC using Hepburn Model in 2021

4.3.1.3 VOC SAVINGS USING HEPBURN MODEL

After computing the VOC values for both the scenarios i.e. with and without BRT, the net peak hourly VOC savings can be find out by using the following equation

$$Net\ VOC\ savings = \ VOC\ without\ BRT - \ VOC\ with\ BRT \qquad (8)$$

$$Net\ VOC\ savings = 1.151 - 0.974$$

$$Net\ VOC\ savings = 0.177\ Million \frac{Rs}{hr}$$

$$Net\ VOC\ savings = 177000 \frac{Rs}{hr}$$

The above results provide the evidence that with the implementation of BRT Peshawar has reduced the vehicle operating cost of the road users. This operating cost has reduced due to the significant impact of reduction in the variables like traffic counts, VMT and an increase in the speed of passenger cars. These variables have resulted in saving 177000 rupees per peak hour. The VOC decreased by 15.37% after the commencement of BRT. Hence it is established that BRT has benefited the people while considering the vehicle operating costs.

4.3.2 VOC USING NTRC VALUES

VOC were also determined for both the conditions i.e. with and without BRT for the same year, that was 2021 by using the values of road user costs that are provided in the study of National Transport Research Centre (NTRC) (Ahmed, 2020). VOC values were computed for both the directions i.e. D-1 and D-3. This study provided the values of road user costs against travelling speed. The value provided was in terms of Rs. /1000 vehicle-km. The following **Table 4-8** was provided by NTRC.

Table 4-8 Road User Costs to Traveling Speed (Rs. /1000 Vehicle-Km) (Ahmed, 2020)

Speed (km/hr)	Motorcycle	Small Car	Medium Car	Wagon	Four Wheel Drive	Light Truck	Medium Truck	Heavy Truck	Articulated Truck	Small Bus	Medium Bus	Large Bus
20	7,060	31,385	40,552	74,718	55,880	35,183	120,203	166,483	197,521	85,219	120,987	185,486
30	6,204	26,626	34,654	63,611	47,204	31,218	109,422	151,188	181,833	73,570	102,602	157,394
40	5,693	23,051	30,213	54,939	40,626	28,614	101,837	141,090	171,973	64,679	88,326	135,569
50	5,605	21,217	27,890	50,176	37,138	27,742	98,401	137,290	168,994	60,090	80,823	123,950
60	5,777	20,324	26,705	47,475	35,304	27,833	97,237	137,077	170,052	57,796	76,907	117,798
70	6,121	20,024	26,234	46,044	34,502	28,477	97,417	139,287	173,856	56,880	75,106	115,096
80	6,540	20,118	26,252	45,456	34,383	29,364	98,279	143,422	179,557	56,789	74,535	114,762
90	6,933	20,446	26,586	45,404	34,677	30,246	99,279	147,863	185,371	57,105	74,566	115,551
100	7,232	20,860	27,078	45,625	35,141	30,980	100,115	147,863	189,832	57,549	74,807	115,551
110	7,430	21,244	27,584	45,916	35,593	31,529	100,402	147,863	191,021	57,967	75,069	115,551

4.3.2.1 VOC of Without BRT Scenario in 2021

The speeds were calculated for both the directions through BPR function. The calculated speed was of PCUs, so all the vehicle classes were converted into PCU by using the PCE factors used by (Adnan, 2014), therefore the road user cost against speed was taken for medium cars only for both the directions i.e. D-1 (towards KTH) and D-3 (towards Hayatabad).

The first step in calculating the VOC was of calculating the Vehicle-KMT for both the directions. It was done by simply multiplying each type of vehicle that was already converted into PCU by the segment length i.e. 2.2 km. Vehicle-KMT values are shown in **Table 4-9** below.

Table 4-9 Calculating Vehicle-KMT for D-1 without BRT scenario

STEP 1													
Calculating Vehicle-KMT													
Time	**Motor-Bike x 0.25**	**Rickshaw x 0.5**	**Car**	**Qingqi x 0.5**	**Suzuki**	**Wagon**	**Mazda / Mini bus x 2.0**	**Rocket x 2.5**	**Large Bus x 2.5**	**Pick-up x 1.5**	**2-axle Truck x 3.0**	**3+-axle Truck x 3.0**	**Tractor x 3.0**
13:15	273.90	94.60	3634.4	-	19.80	94.60	57.20	-	33.00	168.30	-	-	-
13:30	250.25	129.80	2816	-	22.00	103.40	70.40	-	22.00	201.30	-	-	-
13:45	235.95	108.90	2754.4	2.20	24.20	99.00	79.20	-	11.00	181.50	6.60	-	-
14:00	231.00	122.10	2525.6	-	39.60	72.60	61.60	-	27.50	171.60	-	-	-

The second step after calculating the vehicle-KMT was of calculating road user costs. The value of road user cost is provided against speed and is in terms of rupees per 1000 vehicle-KMT. Since the speed in D-1 direction was 19.62 kmph, therefore the value for 20 kmph was selected in this scenario. The value against 20 kmph for medium car was 40552 Rs. / 1000 vehicle-KMT. So this provided value is multiplied with each of the values in **Table 4-10**, which gives us the road user cost.

Table 4-10 Calculating Road User Cost for D-1 without BRT scenario

STEP 2														
Calculating Road User Cost (Rs. / 1000 vehicle-km)														
1/4 Hour	**Motor-Bike x 0.25**	**Rickshaw x 0.5**	**Car**	**Qingqi x 0.5**	**Suzuki**	**Wagon**	**Mazda / Mini bus x 2.0**	**Rocket x 2.5**	**Large Bus x 2.5**	**Pick-up x 1.5**	**2-axle Truck x 3.0**	**3+-axle**	**Tractor x 3.0**
13:15	11,107.19	3,836.22	147382.2	-	802.93	3,836.22	2,319.57	-	1,338.22	6,824.90	-	-	-
13:30	10,148.14	5,263.65	114194.4	-	892.14	4,193.08	2,854.86	-	892.14	8,163.12	-	-	-
13:45	9,568.24	4,416.11	111696.4	89.21	981.36	4,014.65	3,211.72	-	446.07	7,360.19	267.64	-	-
14:00	9,367.51	4,951.40	102418.1	-	1605.859	2,944.08	2,498.00	-	1,115.18	6,958.72	-	-	-

After calculating the road user costs for all the vehicles that were converted into PCUs, the next step was to find out the cost by same procedure for direction-3. The speed in D-3 without BRT scenario was29.94 kmph, therefore the value against this speed of medium cars was taken as 34654 (Rs. /1000 vehicle kmt). And at the end, the 15-minute cost and then total peak hour cost for both the directions i.e. D-1 and D-3 for without BRT scenario was calculated. The **Table 4-11** below shows the 15-minute each and total peak hour cost for both the directions.

Table 4-11 VOC using NTRC values for Without BRT Scenario

Without BRT Scenario	**Time**	**15 Minute Cost**	**Per Peak Hour Cost**
D-1 (towards KTH)	13:15	192074.79	647250.51 or 0.647 (Million Rs)
	13:30	158686.22	
	13:45	153761.23	
	14:00	142728.27	
D-3 (towards Hayatabad)	13:15	91,250.16	378286.88 or 0.378 (Million Rs)
	13:30	92,240.44	
	13:45	96,119.03	
	14:00	98,677.26	

After computing the VOC for both the directions i.e. D-1 and D-3 for without BRT scenario, the net total VOC was find out by the following equation.

$$VOC\ without\ BRT = VOC\ in\ D1 + VOC\ in\ D3 \qquad (9)$$

$$VOC\ without\ BRT = 647250.51 + 378286.88$$

$$VOC\ without\ BRT = 1025537.39 \frac{Rs}{hr}$$

$$VOC\ without\ BRT = 1.025\ Million \frac{Rs}{hr}$$

4.3.2.2 VOC of With BRT Scenario in 2021

Now for finding the VOC for the scenario i.e. with BRT in the year 2021 for both the directions, the same procedure was followed. The speed calculated through BPR function for D-1 direction with BRT scenario was 30.55 kmph and the value provided by NTRC for medium car for speed 30 kmph was 34654 (Rs. / 1000 vehicle-KMT). Whereas the speed on D-3 was 58.15 kmph, so the NTRC road user cost for it was taken as 26705 (Rs. /1000 vehicle-KMT).

The procedure was started by multiplying the PCU with the section length i.e. 2.2 km that resulted in vehicle-KM. The second step was multiplying the vehicle-KM with the road user cost provided by NTRC for both the directions.

And after calculating the road user costs for all the vehicles that were converted into PCUs, the next step was to find out the 15-minute cost and then total peak hour cost for direction-1 and direction-3 i.e. towards KTH and Hayatabad for with BRT scenario. The **Table 4-12** below shows the 15-minute each and total peak hour cost.

Table 4-12 VOC using NTRC values for With BRT Scenario

With BRT Scenario	Time	15 Minute Cost	Per Peak Hour Cost
D-1 (towards KTH)	13:15	126823.2438	502890.1845 Or 0.502 (Million Rs)
	13:30	122896.9456	
	13:45	129396.3033	
	14:00	123773.6918	

D-3 (towards Hayatabad)	13:15	63421.7045	252218.043 or 0.252 (Million Rs)
	13:30	64391.096	
	13:45	62187.9335	
	14:00	62217.309	

After computing the VOC for both the directions i.e. D-1 and D-3 for with BRT scenario, the net total VOC can be find out by the following equation

$$VOC\ with\ BRT = VOC\ in\ D1 + VOC\ in\ D3 \tag{10}$$

$$VOC\ with\ BRT = 502890.1845 + 252218.043$$

$$VOC\ with\ BRT = 755108.2275\frac{Rs}{hr}$$

$$VOC\ with\ BRT = 0.755\ Million\frac{Rs}{hr}$$

The **Figure 4-6** below shows the VOC values for both the scenarios i.e. with and without BRT in the year 2021 that are find out by using the NTRC road user values provided by (Ahmed, 2020). The VOC for without BRT scenario was 1.025 (Million Rs/hr), whereas it came down to 0.755 (Million Rs/hr) for the scenario with BRT.

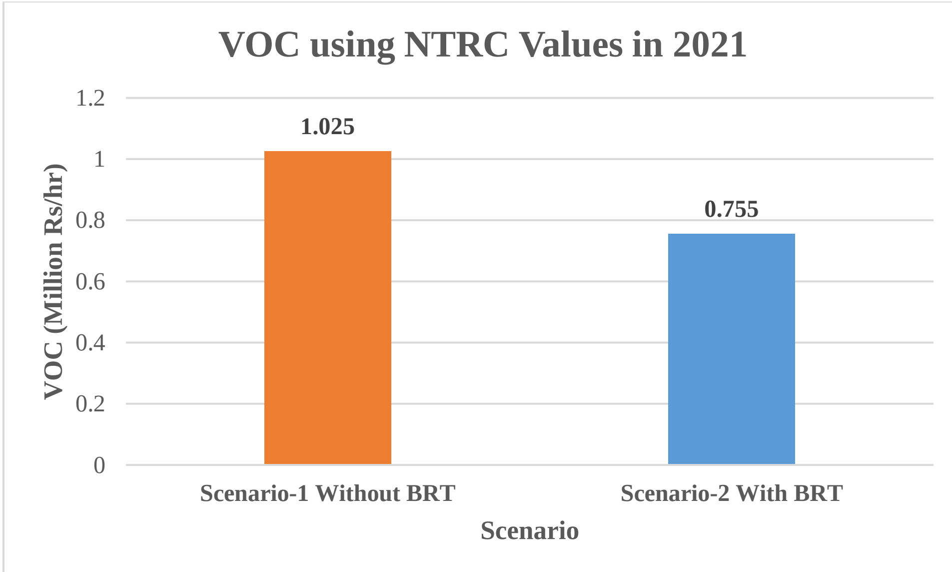

Figure 4-6 VOC using NTRC Values in 2021

4.3.2.3 VOC SAVINGS USING NTRC VALUES

After computing the VOC values for both the scenarios i.e. with and without BRT by using the NTRC values, the net peak hourly VOC savings can be find out by using the following equation.

$$Net\ VOC\ savings = \ VOC\ without\ BRT - \ VOC\ with\ BRT \tag{11}$$

$$Net\ VOC\ savings = \ 1.025 - 0.755$$

$$Net\ VOC\ savings = \ 0.27\ Million\frac{Rs}{hr}$$

$$Net\ VOC\ savings = \ 270000\frac{Rs}{hr}$$

The above results provide the evidence that the BRT Peshawar has reduced the vehicle operating cost of the road users. This operating cost has reduced due to the significant impact of reduction in the variables like traffic counts, VMT and an increase in the speed of passenger cars. These variables have resulted in saving 270000 rupees per peak hour, showing a 26.34% decrease in the VOC after the commencement of BRT. Hence it is established that BRT has benefited the people while considering the vehicle operating costs.

4.4 FUEL EMISSIONS

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 (Singh et al., 2017).

The transportation projects not only provide mobility, accessibility and socio-economic development but at the same time these projects have adverse impacts on environment. 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, BRT like projects helps in the reduction of congestion and makes the flow of vehicles smoother with increased speed which ultimately results in the reduction of pollutants emitted from vehicles. So to check whether the assumptions are valid, the quantity of fuel emission were find out for the two scenarios i.e. with and without BRT by using SYNCHRO 11.

- **SCENARIO 1: WITHOUT BRT**

The first step for finding out the fuel emissions for before BRT scenario was of uploading an up to the scale background image from google earth.

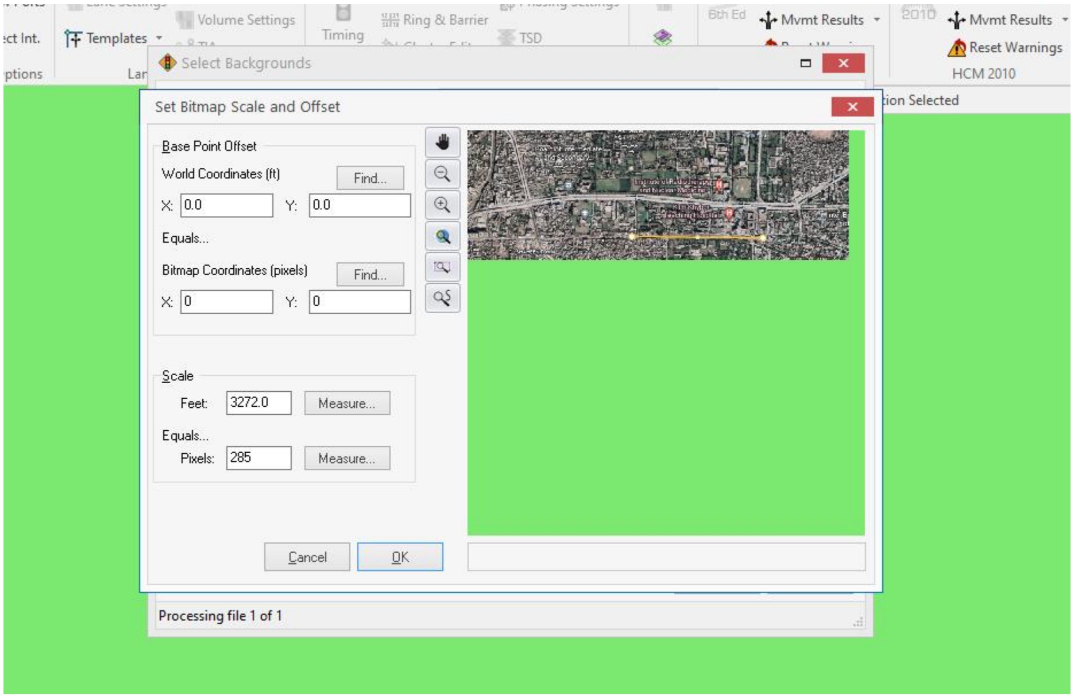

Figure 4-7 Uploading an up to scale background

The second step was adding links to the added up to scaled background image. Before BRT, University road had 3 lanes on either side. A total of 2.2 km section road was drawn.

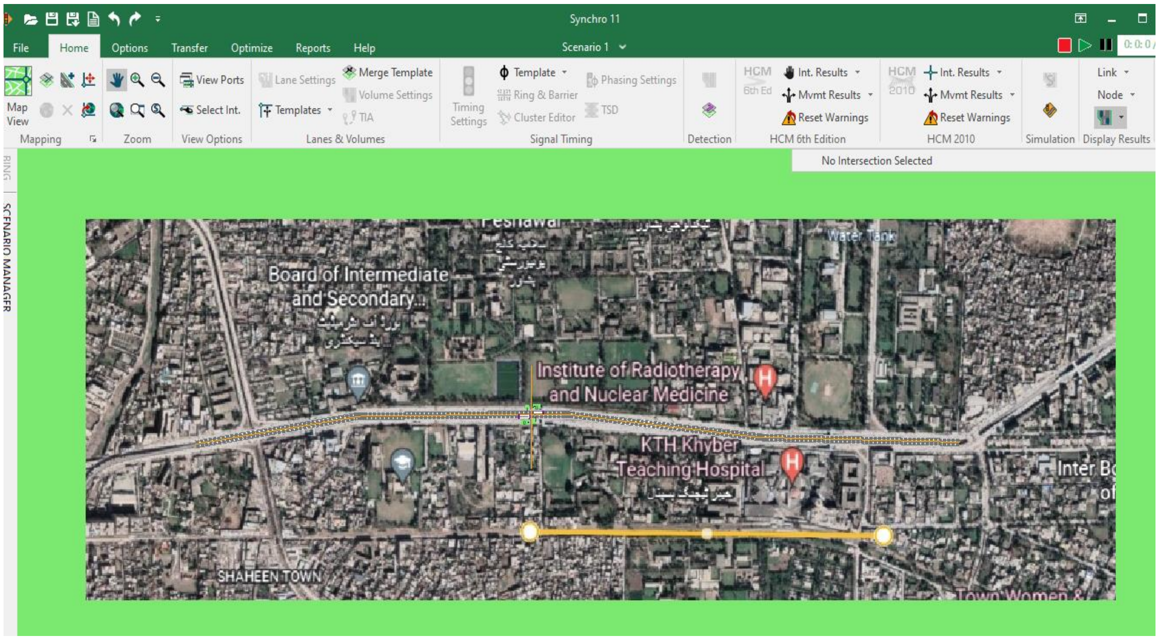

Figure 4-8 Adding Links to the Image

The third step was of adding peak hour volumes for both the direction. The volume of passenger cars travelling on D-1 side towards KTH after applying the growth rate of 2% to the traffic counts in 2017 was 7255 PCUs/hr., having a peak hour factor (PHF) value of 0.84. Whereas, the cars travelling on D-3 side towards Hayatabad were 4962 PCUs/hr in number, having the PHF value of 0.95. They are shown in **Figure 4-9** below.

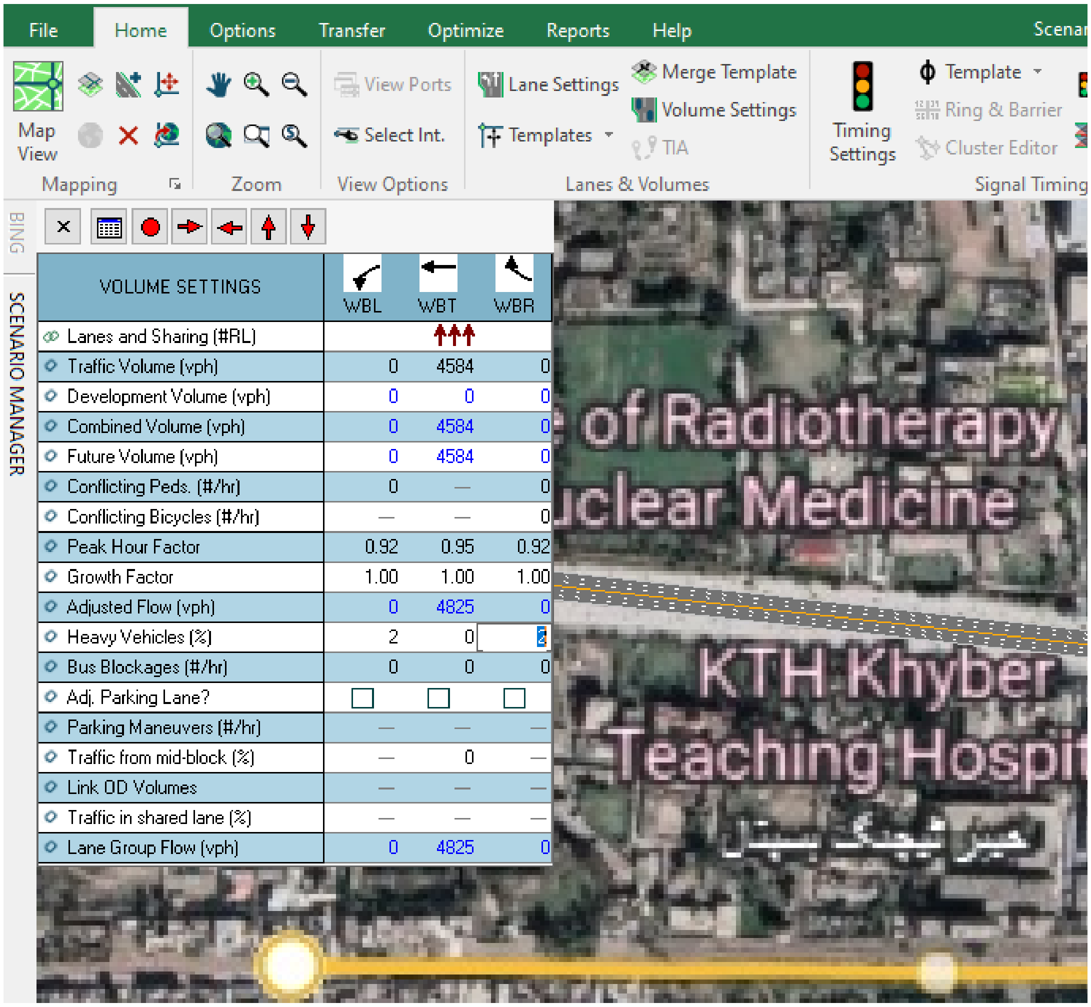

Figure 4-9 Adding Peak Hour Volumes

The final step after adding volumes was of simulation. And then results were generated.

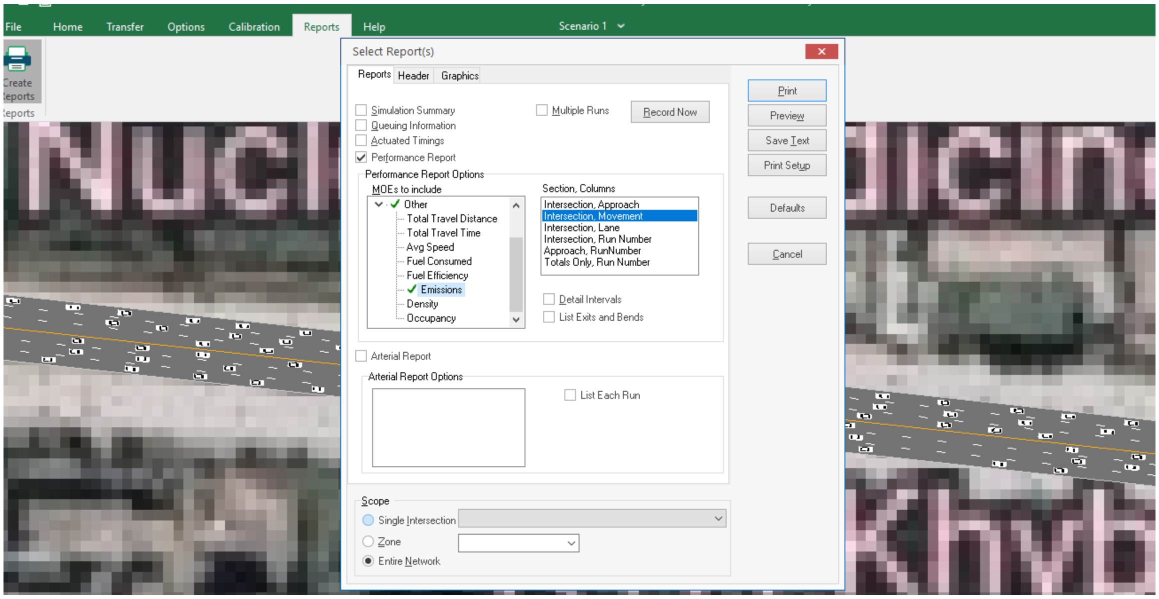

Figure 4-10 After Simulation, Results were Generated

The generated results are shown in the form of a table. The **Table 4-13** provide the values of Hydrocarbons (HC) Emissions, Carbon Monoxide (CO) Emissions and Nitrogen Oxides (NOx) Emissions that are being produced by PCU in an hour. The below table shows that a total of 41g of Hydrocarbon (HC) emissions, 105950g of Carbon Monoxide (CO) emissions and 4565g of Nitrogen Oxides (NOx) emissions were produced by the PCUs in an hour before the implementation of BRT.

Table 4-13 Without BRT Scenario Fuel Emissions

Total Network Performance

HC Emissions (g)	41
CO Emissions (g)	105950
NOx Emissions (g)	4565

- **SCENARIO 2: WITH BRT**

After finding out the fuel emissions produced by PCUs for without BRT scenario, now the second step was of finding the fuel emissions that are being produced by PCUs after the inauguration of BRT on University road Peshawar. Peak hour traffic volumes were used. The volume in D-1 direction towards KTH was 6596 PCUs/hr with the PHF value of 0.971. Whereas, the volume in D-3 direction towards Hayatabad was 4293 PCUs/hr with the PHF value of 0.97. The same procedure that was used for Scenario 1, was used for this scenario. The results stated that 51g Hydrocarbon (HC) Emissions, 80289g of Carbon Monoxide (CO) emissions and 4655g of Nitrogen Oxide (NOx) emissions were produced after the inauguration of BRT on University road. These results are shown in the **Table 4-14** below.

Table 4-14 With BRT Scenario Fuel Emissions

Total Network Performance

HC Emissions (g)	51
CO Emissions (g)	80289
NOx Emissions (g)	4655

After determining the fuel emissions results that are being produced by PCUs for both the scenario i.e. with and without the inauguration of BRT, these results are compared and shown in the **Figure 4-11** below

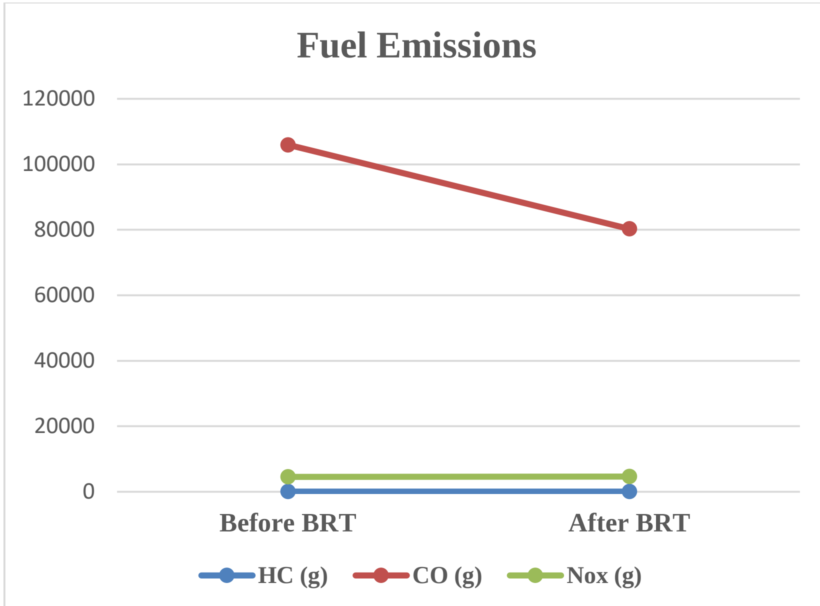

Figure 4-11 Comparison of Fuel Emissions for Both Scenarios

The above results show that Carbon Monoxide (CO) emissions has decreased by 24%. Whereas the quantity of nitrogen oxide (NOx) and Hydrocarbon (HC) have remained stagnated at the level if there wasn't any BRT in same year. Based on the above results it can be stated that the BRT project has been beneficial in terms of reducing the air pollutants in the environment.

4.5 LEVEL OF SERVICE (LOS)

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 BRT 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 BRT has proved the mitigation of congestion, it is important to check its applicability. For this reason, University road was chosen for the analysis of Level of Service (LOS). University road is a major route along which the BRT route traverses.

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.

An arterial's LOS is determined by its maneuverability, delays, and speeds. The likelihood of stopping at an intersection because of a red signal indication rises as the volume increases, and the LOS decreases. According to HCM (Trb, 1997), the level of service of arterial roads can be find based on the travel speed. The **Table 4-15** to determine the LOS of arterial roads is shown below

Table 4-15 LOS Criteria for Arterial Road *(-David Tsela, 2021)*

Level Of Service Criteria For Arterial Road		
S/No.	**Level of Service**	**Travel Speed (mph)**
1.	A	≥ 35
2.	B	≥ 28
3.	C	≥ 22
4.	D	≥ 17
5.	E	≥ 13

6.	F	< 13

With the help of above table, LOS of university for both the scenarios i.e. before and after BRT was calculated. The data of volume for both the directions are taken. The value of capacity for a six lane divided urban road was taken as 5700 PCUs/hr for one direction of flow.

4.5.1 SCENARIO 1 (WITHOUT BRT)

The **Table 4-16** shows the travel speed of scenario 1 i.e. without BRT. After calculating the travel speed by BPR function, LOS can be computed with the help of **Table 4-15** above.

Table 4-16 Computation of LOS for without BRT scenario

Direction 1 (Towards KTH)	Direction 3 (Towards Hayatabad)
Speed = 12.1 mph	Speed = 29.8 mph
LOS = F	LOS = B

4.5.2 SCENARIO 2 (WITH BRT)

The **Table 4-17** shows the travel speed of scenario 2 i.e. with BRT conditions. After calculating the travel speed by BPR function, LOS can be computed with the help of **Table 4-15** above.

Table 4-17 Computation of LOS for with BRT scenario

Direction 1 (Towards KTH)	Direction 3 (Towards Hayatabad)
Speed = 18.89 mph	Speed = 36 mph
LOS = D	LOS = A

The above tables i.e. **Table 4-16** and **Table 4-17** shows that the speed for direction-1 i.e. towards KTH has improved from 12.1 mph to 18.89 mph, changing the LOS from F to D during peak hour. Similarly, the speed for direction-3 i.e. towards Hayatabad has also increased from 29.8 mph to 36 mph for the condition that includes BRT, ultimately resulting in changing the LOS from B to A. So it can be stated that BRT has improved the road conditions when it comes to LOS.

CHAPTER 5: CONCLUSION

5.1 OVERVIEW

Rapid urbanization and increased motorization are having negative effects on the environment, the economy, and the social well-being of people worldwide, causing severe traffic congestion and an unstable transportation system on streets and roads of major cities. Effective public transport (PT) system is one possible approach to the problem of urban road traffic congestion. Due to Peshawar's disorganized, poorly managed, and deteriorating urban transportation system, the Government of Khyber Pakhtunkhwa asked the Cities Development Initiative for Asia for technical assistance in 2013. Due to which the construction of BRT began in 2017 and was completed in 2020.

This research is focused on the evaluation of impact of BRT on travel conditions on adjacent major corridor. A 2.2 km section of University road was selected for analysis. The evaluation framework comprised of three main MOE’s which include vehicle operating cost (VOC), fuel emissions and level of service (LOS) of the road users and vehicles travelling on adjacent road to BRT for two scenarios i.e. with and without implementation of this project. The data required for this evaluation was of traffic counts. For without BRT scenario, traffic counts of 2017 were used, that was brought up to 2021 by applying the growth factor of 2%. Whereas for with BRT, the traffic that were manually counted by myself in 2021 for current scenario were used. Speed data was calculated through BPR function for both the scenarios.

For calculating VOC, a Hepburn Model and NTRC values were used for both the scenarios. For calculating the fuel emissions, all the required data was modeled into

Synchro 11. Whereas, to find the LOS for both the scenarios, a table provided by HCM for finding the LOS for arterial roads based on volume to capacity ratio was used.

5.2 CONCLUSIONS

The conclusion drawn from the analysis of data as mentioned in Chapter 4 are classified as follows

- The speed in direction-1 (towards KTH) has increased by 55.7% i.e. from 19.62 kmph to 30.55 kmph for the scenario that includes BRT. Similarly, the speed in direction-3 (towards Hayatabad) increased by 20.69% i.e. from 48.18 kmph to 58.15 kmph after the commencement of BRT.
- By using Hepburn Model, the VOC decreased by 15.3% for the scenario that includes BRT. Without BRT, the calculated VOC was 1.151 Million Rs/hr. It came down to 0.974 Million Rs/hr. A total of 177000 Rs/hr are being saved by the road users due to this intervention.
- By using NTRC values, the VOC decreased by 26.3% for the scenario that includes BRT. The calculated VOC without BRT was 1.025 Million Rs/hr, whereas it came down to 0.755 Million Rs/hr for the scenario that includes BRT. A total of 270000 Rs/hr are being saved by the road users due to this intervention.
- The amount of Carbon Monoxide (CO) emissions produced by vehicles decreased by 24% for the scenario that includes BRT. Whereas the quantity of Nitrogen Oxide (NOx) and Hydrocarbon (HC) emissions remained stagnated at the same level for both the scenarios.

- The LOS for both the direction improved after the commencement of BRT. In direction-1, the LOS improved from F to D in peak hour. Whereas the LOS increased from B to A in direction-3

RECOMMENDATIONS

- The current research study is focused on assessment of BRT on travel conditions of adjacent corridor. The MOE's include VOC, Fuel emissions and LOS. There are some other important parameters where impact of BRT is need to be assessed which may include safety impacts, social or economic impact analysis.
- In the future regarding the Impact of BRT study, capital cost of BRT should be considered for comprehensive benefit cost analysis.
- Future study should also include travel time reliability impact of BRT on adjacent travel corridor.

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APPENDICES

APPENDIX-A: 24 Hour Traffic counts in 2017, collected by Mott McDonald (Pvt).

APPENDIX A-01: Traffic counts in Direction-1 (Towards KTH)

Traffic Counts Survey - Data

Site #	TC-37	Location	Islamia University	TC-37	Direction	D1	To KTH	Date	17
Day	3	Supervisor				1	Coder	6	

Code						Vehicle Type														
						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Location	Site #	Direction	Date	Day	1/4 Hour	Bicycle	Motor-Bike	Rickshaw	Car	Qingqi	Suzuki	Wagon	Mazda / Mini bus	Rocket	Large Bus	Pick-up	2-axle Truck	3+-axle Truck	Tractor	ADC
TC-37	TC-37	D1	17	3	7:00	9	191	14	316	1	14	12	10	-	3	8	-	-	1	2
TC-37	TC-37	D1	17	3	7:15	7	222	23	603	-	12	26	25	1	4	11	2	-	1	1
TC-37	TC-37	D1	17	3	7:30	11	256	29	824	5	21	40	16	2	3	11	3	-	3	-
TC-37	TC-37	D1	17	3	7:45	14	301	30	964	2	22	21	10	1	1	6	1	-	-	-
TC-37	TC-37	D1	17	3	8:00	15	320	20	1,026	1	13	25	15	-	1	8	1	-	-	-
TC-37	TC-37	D1	17	3	8:15	3	400	55	1,194	1	10	34	9	1	-	7	-	-	-	-
TC-37	TC-37	D1	17	3	8:30	4	409	32	1,185	2	7	23	11	-	-	7	4	-	-	-
TC-37	TC-37	D1	17	3	8:45	4	422	35	1,045	3	14	20	11	1	1	23	-	-	1	1
TC-37	TC-37	D1	17	3	9:00	15	451	47	1,044	2	7	27	15	-	3	16	4	-	-	4
TC-37	TC-37	D1	17	3	9:15	11	455	44	1,011	1	12	24	17	-	2	26	-	-	-	1
TC-37	TC-37	D1	17	3	9:30	3	429	36	940	2	24	29	14	2	-	13	-	-	-	-
TC-37	TC-37	D1	17	3	9:45	6	422	70	1,017	3	14	19	17	1	-	33	-	-	-	-
TC-37	TC-37	D1	17	3	10:00	6	431	33	912	2	12	25	16	1	-	33	1	-	-	-
TC-37	TC-37	D1	17	3	10:15	4	458	42	848	1	7	28	19	-	-	43	-	1	2	1
TC-37	TC-37	D1	17	3	10:30	8	501	43	1,066	4	7	17	15	-	-	24	-	-	-	-
TC-37	TC-37	D1	17	3	10:45	10	522	77	963	2	7	38	16	-	-	48	2	-	-	3
TC-37	TC-37	D1	17	3	11:00	10	539	61	1336	1	6	22	11	3	-	31	1	-	1	1
TC-37	TC-37	D1	17	3	11:15	3	575	97	1460	2	5	45	15	-	-	63	1	-	-	2
TC-37	TC-37	D1	17	3	11:30	9	609	81	1308	2	6	33	15	-	-	49	-	-	-	-
TC-37	TC-37	D1	17	3	11:45	8	555	58	1,250	1	5	39	13	-	-	47	-	-	-	-
TC-37	TC-37	D1	17	3	12:00	9	561	85	1,101	3	12	41	13	-	-	29	-	-	-	-
TC-37	TC-37	D1	17	3	12:15	11	543	46	940	1	12	25	13	-	-	34	-	-	-	-
TC-37	TC-37	D1	17	3	12:30	13	521	77	1,159	-	8	24	11	-	3	54	3	-	-	-
TC-37	TC-37	D1	17	3	12:45	14	525	91	1,225	3	15	41	12	-	5	54	-	-	2	-
TC-37	TC-37	D1	17	3	13:00	36	501	103	1,350	3	9	32	20	-	3	60	1	-	-	-
TC-37	TC-37	D1	17	3	13:15	27	498	86	1,652	-	9	43	13	-	6	51	-	-	-	-
TC-37	TC-37	D1	17	3	13:30	18	455	118	1,280	-	10	47	16	-	4	61	-	-	-	-
TC-37	TC-37	D1	17	3	13:45	13	429	99	1,252	2	11	45	18	-	2	55	1	-	-	-
TC-37	TC-37	D1	17	3	14:00	19	420	111	1,148	-	18	33	14	-	5	52	-	-	-	-
TC-37	TC-37	D1	17	3	14:15	19	423	84	1,042	-	11	35	17	2	1	39	-	-	-	-
TC-37	TC-37	D1	17	3	14:30	4	421	53	736	2	6	12	18	-	2	43	-	-	1	-
TC-37	TC-37	D1	17	3	14:45	2	429	47	914	-	2	17	25	1	-	48	-	-	1	-
TC-37	TC-37	D1	17	3	15:00	1	400	49	1,054	3	1	22	23	-	-	42	-	-	1	1
TC-37	TC-37	D1	17	3	15:15	8	385	60	882	2	5	19	24	-	-	41	2	-	-	-
TC-37	TC-37	D1	17	3	15:30	9	364	45	1,046	1	6	14	17	-	-	51	1	-	-	-
TC-37	TC-37	D1	17	3	15:45	17	363	51	904	1	10	14	13	-	-	41	-	-	-	-
TC-37	TC-37	D1	17	3	16:00	14	375	42	1,136	1	6	18	11	2	-	39	2	-	-	-
TC-37	TC-37	D1	17	3	16:15	12	330	53	809	-	13	15	13	4	-	40	-	-	-	-

TC-37	TC-37	D1	17	3	16:30	11	359	49	775	-	5	14	9	3	-	37	-	-	1	-
TC-37	TC-37	D1	17	3	16:45	12	325	53	734	1	4	19	8	1	-	45	1	-	-	1
TC-37	TC-37	D1	17	3	17:00	12	302	44	702	3	5	15	18	-	-	44	-	-	-	-
TC-37	TC-37	D1	17	3	17:15	19	305	56	880	-	6	21	16	3	-	56	-	-	-	1
TC-37	TC-37	D1	17	3	17:30	8	298	44	824	-	7	21	17	2	-	38	-	-	-	-
TC-37	TC-37	D1	17	3	17:45	7	305	48	809	-	11	21	17	3	1	37	-	-	-	-
TC-37	TC-37	D1	17	3	18:00	15	300	42	920	1	8	17	5	1	-	31	-	-	2	1
TC-37	TC-37	D1	17	3	18:15	8	287	48	860	1	1	14	11	3	-	38	3	-	-	-
TC-37	TC-37	D1	17	3	18:30	6	307	41	987	1	2	11	5	1	-	48	-	-	2	2
TC-37	TC-37	D1	17	3	18:45	12	300	46	939	1	6	15	10	1	-	39	-	-	1	-
TC-37	TC-37	D1	17	3	19:00	11	331	43	990	1	2	16	2	3	-	38	-	-	-	-
TC-37	TC-37	D1	17	3	19:15	20	311	39	963	1	6	22	7	2	-	44	-	-	-	1
TC-37	TC-37	D1	17	3	19:30	18	325	43	1,035	4	7	17	5	-	-	45	-	-	-	-
TC-37	TC-37	D1	17	3	19:45	10	354	27	991	2	8	14	7	-	-	34	-	-	-	-
TC-37	TC-37	D1	17	3	20:00	12	395	36	819	4	9	11	1	-	-	55	-	-	-	1
TC-37	TC-37	D1	17	3	20:15	8	323	34	857	-	4	15	3	-	-	25	-	-	-	1
TC-37	TC-37	D1	17	3	20:30	8	323	22	877	1	7	11	1	1	2	33	-	-	1	1
TC-37	TC-37	D1	17	3	20:45	2	308	39	906	1	3	6	4	-	2	25	-	-	7	1
TC-37	TC-37	D1	17	3	21:00	9	331	33	720	1	6	9	2	-	-	24	-	-	1	-
TC-37	TC-37	D1	17	3	21:15	6	284	22	697	2	4	8	-	-	-	32	4	-	1	-
TC-37	TC-37	D1	17	3	21:30	5	224	27	670	4	7	8	-	-	-	16	1	-	1	1
TC-37	TC-37	D1	17	3	21:45	1	198	19	643	1	2	3	-	-	-	20	1	-	3	-
TC-37	TC-37	D1	17	3	22:00	3	173	21	650	-	2	5	1	1	-	21	-	-	-	-
TC-37	TC-37	D1	17	3	22:15	1	121	25	611	1	1	10	4	1	1	17	-	-	-	-
TC-37	TC-37	D1	17	3	22:30	-	111	19	623	1	3	11	1	-	-	10	-	-	-	-
TC-37	TC-37	D1	17	3	22:45	-	109	10	511	-	1	9	1	-	5	12	-	-	-	-
TC-37	TC-37	D1	17	3	23:00	1	99	4	553	-	2	9	-	-	4	5	-	-	-	-
TC-37	TC-37	D1	17	3	23:15	-	75	-	491	1	-	7	-		1	5	-	-	-	-
TC-37	TC-37	D1	17	3	23:30	-	69	3	433	2	1	5	3	1	2	7	-	-	-	-
TC-37	TC-37	D1	17	3	23:45	2	53	1	379	-	3	5	3	-	-	2	-	-	-	-
TC-37	TC-37	D1	17	3	0:00	-	56	2	311	-	1	3	1	-	-	2	-	-	-	-
TC-37	TC-37	D1	17	3	0:15	-	33	2	271	-	-	2	1	-	-	-	2	-	-	-
TC-37	TC-37	D1	17	3	0:30	1	31	2	222	1	-	2	-	-	-	-	2	1	-	-
TC-37	TC-37	D1	17	3	0:45	1	36	-	187	-	2	5	-	-	-	-	-	-	-	-
TC-37	TC-37	D1	17	3	1:00	-	23	-	141	-	-	1	-	-	-	1	-	-	-	-
TC-37	TC-37	D1	17	3	1:15	1	15	-	98	-	-	-	-	-	-	-	1	-	-	-
TC-37	TC-37	D1	17	3	1:30	-	7	1	51	-	1	-	-	-	-	-	1	2	-	-
TC-37	TC-37	D1	17	3	1:45	-	8	-	57	-	-	-	-	-	-	3	-	-	-	-
TC-37	TC-37	D1	17	3	2:00	-	-	-	12	-	-	-	-	-	1	-	-	-	-	-
TC-37	TC-37	D1	17	3	2:15	1	1	2	7	-	-	-	-	-	-	-	-	-	-	-
TC-37	TC-37	D1	17	3	2:30	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-
TC-37	TC-37	D1	17	3	2:45	-	-	-	7	-	-	-	-	-	-	5	-	2	-	-
TC-37	TC-37	D1	17	3	3:00	-	3	1	8	-	-	-	-	-	-	-	-	-	-	-
TC-37	TC-37	D1	17	3	3:15	-	-	-	2	-	-	-	-	-	1	2	-	-	-	-
TC-37	TC-37	D1	17	3	3:30	-	-	-	1	-	1	-	-	-	-	3	-	-	-	-
TC-37	TC-37	D1	17	3	3:45	-	1	-	1	-	-	-	-	-	1	1	-	-	-	-
TC-37	TC-37	D1	17	3	4:00	1	-	1	2	-	-	-	-	-	-	1	-	-	-	-
TC-37	TC-37	D1	17	3	4:15	-	-	3	5	-	1	-	-	-	-	5	-	-	-	-
TC-37	TC-37	D1	17	3	4:30	2	2	1	2	-	-	-	-	-	-	1	-	-	-	-
TC-37	TC-37	D1	17	3	4:45	1	-	-	10	-	-	-	-	-	2	2	-	-	-	-
TC-37	TC-37	D1	17	3	5:00	3	1	4	15	-	1	-	-	-	1	-	1	-	-	-
TC-37	TC-37	D1	17	3	5:15	-	17	1	18	1	2	3	2	-	-	-	1	-	-	-
TC-37	TC-37	D1	17	3	5:30	1	21	-	33	-	3	1	5	-	-	-	-	-	-	-
TC-37	TC-37	D1	17	3	5:45	1	39	9	52	1	1	5	1	-	-	2	-	-	-	-
TC-37	TC-37	D1	17	3	6:00	3	33	13	81	3	1	7	1	2	-	5	-	-	-	-
TC-37	TC-37	D1	17	3	6:15	4	51	11	153	2	5	12	5	1	-	-	-	-	-	-
TC-37	TC-37	D1	17	3	6:30	6	79	25	223	1	7	18	6	-	-	3	-	-	-	-
TC-37	TC-37	D1	17	3	6:45	5	95	21	297	4	7	21	8	2	-	1	-	-	-	-
					TOTAL	664	**24,568**	**3,264**	**65,063**	**108**	**555**	**1,493**	**772**	**54**	**73**	**2,261**	**48**	**6**	**34**	28

APPENDIX A-02: Traffic Counts in Direction-3 (Towards Hayatabad)

Traffic Counts Survey - Data

Site # TC-37 **Location** Islamia University TC-37 **Direction** D3 To Hayatabad **Date** 17

Day 3 **Supervisor** 1 **Coder** 6

Code						Vehicle Type														
						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Location	Site #	Direction	Date	Day	1/4 Hour	Bicycle	Motor-Bike	Rickshaw	Car	Qingqi	Suzuki	Wagon	Mazda / Mini bus	Rocket	Large Bus	Pick-up	2-axle Truck	3+-axle Truck	Tractor	ADC
TC-37	TC-37	D3	17	3	7:00	33	143	11	458	4	19	25	15	3	5	20	-	-	-	-
TC-37	TC-37	D3	17	3	7:15	27	160	14	572	3	9	22	21	19	3	10	-	-	-	-
TC-37	TC-37	D3	17	3	7:30	24	165	22	516	3	12	26	32	7	4	10	-	-	1	2
TC-37	TC-37	D3	17	3	7:45	28	173	25	724	1	7	27	19	3	8	10	-	-	-	-
TC-37	TC-37	D3	17	3	8:00	16	177	37	694	2	9	25	10	2	6	15	-	-	-	1
TC-37	TC-37	D3	17	3	8:15	14	170	40	747	4	15	27	10	1	7	19	-	-	-	2
TC-37	TC-37	D3	17	3	8:30	20	255	35	772	1	3	18	15	1	4	19	-	-	1	-
TC-37	TC-37	D3	17	3	8:45	9	239	28	781	-	9	19	18	2	4	21	-	-	-	-
TC-37	TC-37	D3	17	3	9:00	10	244	34	821	1	2	30	13	1	3	15	-	-	-	2
TC-37	TC-37	D3	17	3	9:15	8	249	31	753	3	8	28	15	2	1	17	-	-	-	1
TC-37	TC-37	D3	17	3	9:30	15	256	39	787	2	7	21	10	1	-	18	-	-	1	-
TC-37	TC-37	D3	17	3	9:45	9	275	22	760	2	1	15	11	1	-	14	-	-	1	1
TC-37	TC-37	D3	17	3	10:00	6	277	25	808	1	3	27	15	2	-	20	-	-	-	-
TC-37	TC-37	D3	17	3	10:15	8	201	24	698	1	3	16	12	2	-	10	-	-	1	-
TC-37	TC-37	D3	17	3	10:30	12	209	41	680	-	7	28	16	1	-	12	-	-	-	-
TC-37	TC-37	D3	17	3	10:45	2	205	49	683	2	4	31	16	2	-	21	-	-	-	-
TC-37	TC-37	D3	17	3	11:00	5	211	27	695	3	5	36	9	2	-	15	-	-	1	-
TC-37	TC-37	D3	17	3	11:15	9	217	38	711	3	6	23	13	3	-	22	-	-	4	-
TC-37	TC-37	D3	17	3	11:30	5	233	41	729	4	1	20	13	1	-	18	-	-	-	-
TC-37	TC-37	D3	17	3	11:45	5	228	34	747	-	3	11	12	-	1	17	-	-	1	-
TC-37	TC-37	D3	17	3	12:00	7	235	29	750	2	9	11	7	1	-	28	-	-	-	-
TC-37	TC-37	D3	17	3	12:15	9	250	33	759	2	7	18	11	1	-	11	-	-	2	-
TC-37	TC-37	D3	17	3	12:30	6	201	31	793	1	6	19	15	2	2	18	-	-	1	-
TC-37	TC-37	D3	17	3	12:45	5	185	41	889	3	17	21	25	1	3	17	-	-	2	1
TC-37	TC-37	D3	17	3	13:00	2	188	29	920	4	25	17	14	2	5	11	-	-	-	4
TC-37	TC-37	D3	17	3	13:15	7	195	36	922	1	33	17	13	1	5	17	-	-	-	-
TC-37	TC-37	D3	17	3	13:30	4	191	38	927	1	30	15	12	1	10	18	-	-	-	-
TC-37	TC-37	D3	17	3	13:45	7	201	24	960	2	19	16	13	5	11	21	-	1	2	-
TC-37	TC-37	D3	17	3	14:00	10	215	26	976	-	8	21	20	3	15	26	-	-	-	-
TC-37	TC-37	D3	17	3	14:15	5	218	33	986	-	4	15	13	-	9	18	-	-	-	-
TC-37	TC-37	D3	17	3	14:30	6	235	39	922	1	7	19	14	2	7	21	-	-	-	-
TC-37	TC-37	D3	17	3	14:45	12	234	46	846	1	13	17	11	1	4	30	-	-	-	-
TC-37	TC-37	D3	17	3	15:00	12	232	55	809	2	5	17	10	1	-	20	1	-	-	-
TC-37	TC-37	D3	17	3	15:15	10	239	51	779	2	5	18	8	2	-	31	-	-	-	-
TC-37	TC-37	D3	17	3	15:30	6	265	57	748	1	2	15	9	3	-	25	-	-	-	-
TC-37	TC-37	D3	17	3	15:45	5	281	55	708	3	2	16	7	1	2	19	-	-	1	-
TC-37	TC-37	D3	17	3	16:00	4	330	41	747	1	5	16	10	2	-	26	-	-	1	-
TC-37	TC-37	D3	17	3	16:15	10	351	39	751	1	4	20	11	3	1	26	-	-	-	-

TC-37	TC-37	D3	17	3	16:30	3	381	41	780	1	6	20	10	3	-	21	-	-	-	1
TC-37	TC-37	D3	17	3	16:45	17	370	55	801	1	4	14	10	1	-	33	1	-	-	-
TC-37	TC-37	D3	17	3	17:00	5	371	51	822	5	4	20	8	3	-	17	-	-	-	-
TC-37	TC-37	D3	17	3	17:15	6	384	59	856	-	2	20	5	2	5	32	-	-	-	2
TC-37	TC-37	D3	17	3	17:30	8	366	69	871	1	1	17	8	-	9	30	-	-	-	1
TC-37	TC-37	D3	17	3	17:45	14	370	81	901	-	1	12	10	1	7	25	-	-	-	-
TC-37	TC-37	D3	17	3	18:00	13	378	88	921	-	2	8	7	2	-	24	-	-	-	-
TC-37	TC-37	D3	17	3	18:15	8	391	108	999	1	2	8	6	-	-	24	-	-	-	1
TC-37	TC-37	D3	17	3	18:30	8	400	100	987	-	4	19	8	-	-	35	-	-	-	1
TC-37	TC-37	D3	17	3	18:45	5	401	128	991	-	5	28	9	2	1	30	-	-	-	1
TC-37	TC-37	D3	17	3	19:00	7	421	121	997	-	1	22	8	1	3	21	-	-	-	-
TC-37	TC-37	D3	17	3	19:15	4	417	109	983	2	1	11	7	2	-	19	-	-	2	-
TC-37	TC-37	D3	17	3	19:30	11	411	111	979	1	4	17	7	-	-	20	-	-	-	1
TC-37	TC-37	D3	17	3	19:45	7	591	107	977	2	1	10	6	1	-	25	-	-	-	-
TC-37	TC-37	D3	17	3	20:00	5	603	98	961	-	1	8	4	-	-	21	1	-	-	-
TC-37	TC-37	D3	17	3	20:15	3	622	91	973	-	1	4	2	2	1	14	-	-	-	-
TC-37	TC-37	D3	17	3	20:30	3	621	87	979	1	-	11	3	-	-	16	-	-	-	-
TC-37	TC-37	D3	17	3	20:45	-	653	81	988	1	2	5	4	2	-	20	1	-	2	-
TC-37	TC-37	D3	17	3	21:00	7	651	12	981	-	2	7	4	1	-	20	-	-	5	-
TC-37	TC-37	D3	17	3	21:15	7	641	14	970	-	-	2	1	-	2	19	-	-	-	1
TC-37	TC-37	D3	17	3	21:30	4	639	7	963	-	-	3	1	3	-	17	1	-	-	-
TC-37	TC-37	D3	17	3	21:45	1	633	14	955	-	-	7	1	2	1	11	2	-	-	-
TC-37	TC-37	D3	17	3	22:00	2	640	11	911	-	1	9	2	-	1	10	-	-	-	-
TC-37	TC-37	D3	17	3	22:15	1	601	8	901	-	-	10	-	2	-	12	-	-	-	-
TC-37	TC-37	D3	17	3	22:30	1	531	12	863	-	-	8	1	1	2	11	-	-	-	-
TC-37	TC-37	D3	17	3	22:45	-	520	5	813	1	1	11	3	-	1	5	-	-	-	1
TC-37	TC-37	D3	17	3	23:00	-	522	11	716	3	-	10	-	3	-	4	-	-	-	1
TC-37	TC-37	D3	17	3	23:15	3	521	13	688	1	3	15	-	1	-	5	-	-	-	-
TC-37	TC-37	D3	17	3	23:30	1	499	10	613	2	-	5	-	-	-	1	1	-	-	-
TC-37	TC-37	D3	17	3	23:45	-	430	3	591	-	-	11	1	1	1	-	-	-	-	1
TC-37	TC-37	D3	17	3	0:00	1	411	-	570	-	-	17	-	-	-	2	2	-	-	1
TC-37	TC-37	D3	17	3	0:15	-	331	2	533	1	-	10	-	-	-	-	2	-	-	-
TC-37	TC-37	D3	17	3	0:30	-	208	5	481	-	-	9	2	-	-	-	-	-	-	-
TC-37	TC-37	D3	17	3	0:45	2	142	1	401	-	1	5	1	-	-	1	-	-	-	1
TC-37	TC-37	D3	17	3	1:00	1	98	2	322	1	-	7	-	-	-	-	-	-	-	-
TC-37	TC-37	D3	17	3	1:15	-	103	-	155	-	-	1	-	-	-	-	-	-	-	-
TC-37	TC-37	D3	17	3	1:30	-	60	-	151	-	-	-	2	-	-	-	-	-	1	-
TC-37	TC-37	D3	17	3	1:45	1	37	-	110	-	-	-	-	-	-	3	-	1	-	-
TC-37	TC-37	D3	17	3	2:00	-	17	1	76	-	-	1	-	-	-	-	-	-	-	-
TC-37	TC-37	D3	17	3	2:15	-	8	1	39	-	-	-	1	-	-	-	-	-	-	-
TC-37	TC-37	D3	17	3	2:30	-	7	2	30	-	-	-	-	-	-	-	-	-	1	-
TC-37	TC-37	D3	17	3	2:45	-	2	1	21	-	-	-	-	-	-	-	-	2	-	-
TC-37	TC-37	D3	17	3	3:00	1	1	-	17	-	-	-	-	-	-	-	-	-	-	-
TC-37	TC-37	D3	17	3	3:15	-	1	-	9	-	-	-	-	-	-	-	-	-	-	-
TC-37	TC-37	D3	17	3	3:30	-	-	-	3	-	-	-	1	-	-	-	-	-	-	-
TC-37	TC-37	D3	17	3	3:45	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-
TC-37	TC-37	D3	17	3	4:00	1	-	-	-	1	-	-	-	-	-	1	-	-	-	-
TC-37	TC-37	D3	17	3	4:15	-	3	-	7	-	1	-	-	-	-	1	-	-	1	-
TC-37	TC-37	D3	17	3	4:30	-	-	-	5	2	-	-	-	-	-	-	-	-	-	1
TC-37	TC-37	D3	17	3	4:45	-	-	-	3	1	2	-	-	-	-	-	-	-	-	-
TC-37	TC-37	D3	17	3	5:00	-	1	-	11	-	-	-	1	-	-	-	1	1	-	-
TC-37	TC-37	D3	17	3	5:15	2	9	1	19	-	-	1	-	1	1	2	3	-	-	-
TC-37	TC-37	D3	17	3	5:30	1	11	3	39	2	3	3	1	-	1	1	1	-	-	1
TC-37	TC-37	D3	17	3	5:45	3	53	-	55	-	2	5	-	2	-	-	2	-	2	2
TC-37	TC-37	D3	17	3	6:00	5	85	7	81	-	6	10	-	-	-	5	1	-	-	1
TC-37	TC-37	D3	17	3	6:15	13	100	11	151	2	8	15	3	-	2	5	1	-	-	-
TC-37	TC-37	D3	17	3	6:30	10	107	19	176	-	11	21	9	1	1	9	1	-	-	-
TC-37	TC-37	D3	17	3	6:45	17	101	10	233	3	15	20	10	2	1	14	-	-	-	1
					TOTAL	604	**25408**	**3091**	**59762**	**104**	**432**	**1260**	**685**	**130**	**160**	**1292**	**22**	**5**	**34**	34

APPENDIX-B: 24 Hours Traffic Count Data on University Road (After BRT) in 2021.

APPENDIX B-01: Traffic Counts in Direction-1 (Towards KTH)

D1 - From Hayatabad towards KTH										
TIME (1/4) HOURS	1	2	3	4	5	6	7	8	9	10
	MOTORBIKE	RICKSHAW	CAR	QINGQI	SUZUKI	WAGON	MAZDA/ MINI BUS	ROCKET	PICK-UP	LARGE BUS
7:00	251	10	485	0	14	0	0	0	10	2
7:15	293	5	675	1	12	0	0	0	13	5
7:30	320	11	901	2	16	0	0	0	14	0
7:45	355	12	993	1	20	0	0	0	15	1
8:00	381	7	1085	0	23	0	0	0	12	0
8:15	410	6	1235	1	20	0	0	0	14	0
8:30	450	7	1220	0	18	0	0	0	10	0
8:45	491	8	1232	2	17	0	1	0	15	0
9:00	520	3	1205	1	16	0	0	0	17	0
9:15	540	6	1176	0	14	1	0	0	18	0
9:30	508	5	1109	1	16	0	0	0	19	0
9:45	595	2	1085	1	17	0	0	0	20	0
10:00	486	8	1032	0	12	0	0	0	21	0
10:15	510	3	998	1	11	0	0	0	24	0
10:30	526	8	921	1	9	0	1	0	25	0
10:45	551	7	935	0	13	1	0	0	23	0
11:00	565	3	941	1	11	0	0	0	18	0
11:15	551	8	901	2	10	1	0	0	19	0
11:30	538	3	922	1	8	0	0	0	17	0
11:45	546	1	920	1	7	0	1	0	19	0
12:00	571	9	932	1	9	0	0	0	22	0
12:15	553	8	989	0	7	1	0	0	25	0
12:30	548	11	1098	1	8	0	0	1	29	0
12:45	595	8	1208	0	10	0	0	0	31	0
13:00	611	7	1365	1	12	0	0	0	30	0
13:15	646	13	1560	0	10	0	0	0	33	0
13:30	619	19	1612	0	14	0	0	1	35	0
13:45	589	21	1593	1	16	0	0	0	37	0
14:00	573	7	1533	0	19	0	0	0	35	0
14:15	522	11	1432	1	15	1	0	0	33	1
14:30	515	8	1396	0	11	0	0	0	30	0
14:45	469	11	1221	0	9	1	0	0	21	0
15:00	422	5	1105	1	9	0	0	0	22	0
15:15	413	7	1071	1	5	0	1	0	23	0
15:30	401	7	1023	0	6	0	0	0	20	0
15:45	396	10	1011	1	4	0	0	0	14	0
16:00	376	5	923	0	3	0	0	0	13	0
16:15	365	3	851	1	9	0	0	0	15	0
16:30	359	8	863	1	7	0	0	0	14	0
16:45	350	2	801	0	9	0	0	1	12	0
17:00	332	6	796	1	7	0	0	0	15	0
17:15	315	3	856	0	11	1	0	0	16	0
17:30	308	4	901	0	13	0	1	0	11	0
17:45	319	1	965	0	10	0	0	0	14	0
18:00	310	4	1003	1	10	0	0	0	19	0
18:15	307	3	1023	1	12	1	0	0	25	0
18:30	301	6	1085	0	9	0	0	0	22	0
18:45	295	11	1103	1	8	0	1	0	24	0
19:00	331	10	1136	1	5	0	0	0	24	0
19:15	340	13	1185	0	3	0	0	0	16	0

19:30	366	19	1201	1	5	0	0	0	15	0
19:45	384	15	1185	0	4	0	0	0	17	0
20:00	399	10	1095	1	3	0	0	0	10	0
20:15	375	13	1005	0	3	0	0	0	15	0
20:30	336	15	953	1	2	0	0	1	12	0
20:45	329	11	901	0	1	0	0	0	16	0
21:00	330	8	851	1	2	0	0	0	17	0
21:15	295	6	793	0	3	0	0	1	20	0
21:30	246	7	701	0	2	0	0	0	14	0
21:45	215	3	685	0	4	1	0	0	13	0
22:00	194	1	659	0	1	0	0	0	15	0
22:15	146	2	630	1	2	0	0	0	14	0
22:30	112	0	601	0	1	0	0	0	11	2
22:45	106	1	555	1	2	0	0	0	7	2
23:00	91	2	401	0	1	0	0	0	5	0
23:15	74	1	315	0	0	0	0	0	6	0
23:30	59	0	256	0	0	0	0	0	3	0
23:45	55	1	185	0	1	0	0	0	1	1
0:00	48	1	101	0	0	0	0	0	3	0
0:15	36	1	45	0	0	0	0	0	2	1
0:30	28	0	56	0	1	0	0	0	0	0
0:45	19	0	51	0	1	0	0	0	1	1
1:00	8	0	29	0	0	0	0	0	0	1
1:15	11	1	23	0	0	0	0	0	0	0
1:30	5	0	15	0	1	0	0	0	0	1
1:45	3	0	14	0	0	0	0	0	1	0
2:00	0	1	13	0	0	0	0	0	0	0
2:15	0	1	5	0	0	0	0	0	0	1
2:30	1	0	6	0	0	0	0	0	0	0
2:45	0	0	9	0	0	0	0	0	0	0
3:00	1	0	5	0	0	0	0	0	0	2
3:15	0	0	3	0	0	0	0	0	0	0
3:30	0	1	2	0	0	0	0	0	0	0
3:45	0	0	0	0	0	0	0	0	0	1
4:00	0	1	1	0	0	0	0	0	0	0
4:15	1	1	2	0	0	0	0	0	0	1
4:30	1	0	1	0	0	0	0	0	0	0
4:45	5	0	5	0	0	0	0	0	0	1
5:00	11	2	19	0	0	0	0	0	0	1
5:15	21	1	26	0	1	0	0	0	1	0
5:30	39	3	37	0	1	0	0	0	1	1
5:45	57	3	61	0	1	0	0	0	2	0
6:00	65	5	95	1	3	0	0	0	4	1
6:15	79	7	175	0	5	0	0	0	7	0
6:30	95	5	263	0	9	0	1	0	10	1
6:45	111	3	385	0	13	0	0	0	5	0
TOTAL	27195	516	68030	39	637	9	7	5	1271	28

APPENDIX B-02: Traffic Counts in Direction-3 (Towards Hayatabad)

D3 - From KTH towards Hayatabad										
TIME (1/4) HOURS	1	2	3	4	5	6	7	8	9	10
	MOTORBIKE	RICKSHAW	CAR	QINGQI	SUZUKI	WAGON	MAZDA/ MINI BUS	ROCKET	PICK-UP	LARGE BUS
7:00	145	6	506	1	11	0	0	0	8	2
7:15	185	11	565	1	10	0	0	0	14	4
7:30	211	7	643	1	13	0	0	1	13	3
7:45	260	6	742	0	15	0	0	0	10	1
8:00	265	7	799	1	19	0	0	0	7	2
8:15	295	8	843	0	23	0	0	0	15	0
8:30	286	6	865	0	21	0	1	0	13	1
8:45	311	5	913	1	20	0	0	0	15	0
9:00	385	8	921	1	15	0	0	0	8	0
9:15	403	8	950	0	16	1	0	0	12	0
9:30	411	7	955	1	12	0	0	0	11	0
9:45	433	6	951	1	13	0	0	0	13	0
10:00	385	6	950	0	15	0	0	0	13	0
10:15	376	5	835	1	13	0	0	0	12	0
10:30	406	11	805	0	8	1	0	0	10	0
10:45	413	9	793	1	6	0	0	0	9	0
11:00	445	7	795	1	13	0	0	0	7	0
11:15	441	7	800	0	15	0	0	0	10	0
11:30	438	8	841	1	5	0	0	0	11	0
11:45	471	7	861	0	9	0	0	0	9	0
12:00	505	9	909	1	8	0	0	0	14	0
12:15	510	8	846	0	5	0	0	0	10	0
12:30	518	11	901	0	9	0	0	0	8	0
12:45	533	9	963	0	15	0	0	0	9	0
13:00	550	8	1013	0	13	0	0	0	15	0
13:15	541	14	1021	1	21	1	0	1	16	0
13:30	544	12	1053	0	12	0	0	0	19	0
13:45	536	13	1028	0	13	1	0	0	20	0
14:00	522	8	1004	0	17	0	1	0	15	0
14:15	515	6	1009	1	14	0	0	0	16	0
14:30	469	5	959	0	13	0	0	0	18	0
14:45	422	7	927	0	8	0	0	0	19	0
15:00	413	3	877	1	8	0	0	0	20	0
15:15	401	5	851	0	6	0	1	0	15	0
15:30	396	5	795	0	7	0	0	0	14	0
15:45	376	6	772	0	7	0	0	0	7	0
16:00	356	3	801	0	6	0	0	0	11	0
16:15	349	2	843	1	9	0	0	0	19	0
16:30	340	5	885	0	5	0	0	0	25	0
16:45	333	2	905	0	5	0	0	0	20	0
17:00	315	4	953	1	8	0	0	0	21	0
17:15	308	3	988	0	13	1	0	0	17	0
17:30	319	4	1029	0	14	0	1	0	13	0
17:45	310	1	1068	1	11	0	0	0	15	0
18:00	307	2	1126	0	6	0	0	0	16	0
18:15	301	2	1159	0	7	0	0	0	15	0
18:30	295	5	1236	1	5	0	0	1	10	0
18:45	336	7	1255	0	9	0	0	0	11	0
19:00	416	4	1268	1	4	0	0	0	9	0
19:15	461	9	1250	0	5	0	0	0	16	0
19:30	509	11	1248	1	3	0	0	0	15	0

19:45	546	8	1276	0	1	1	0	0	18	0
20:00	601	6	1208	1	1	0	0	0	11	0
20:15	574	7	1145	0	0	0	0	0	13	0
20:30	545	6	1117	0	0	0	0	0	10	0
20:45	506	6	1033	0	0	0	0	0	15	0
21:00	440	4	1053	0	1	1	0	0	9	0
21:15	395	4	1001	0	1	0	0	0	7	0
21:30	330	3	1005	0	3	0	0	0	10	0
21:45	305	1	908	1	1	0	1	0	10	0
22:00	285	1	789	0	1	0	0	0	7	0
22:15	245	2	760	0	1	0	0	0	13	0
22:30	202	1	701	0	0	0	0	0	10	0
22:45	175	1	669	0	0	0	0	0	11	0
23:00	146	0	625	0	0	0	0	0	5	0
23:15	121	1	489	0	1	0	0	0	4	0
23:30	89	0	423	0	0	0	0	0	1	1
23:45	55	1	385	0	0	0	0	0	0	2
0:00	48	0	300	0	0	0	0	0	0	0
0:15	36	1	189	0	1	0	0	0	1	0
0:30	28	0	113	0	0	0	0	0	0	0
0:45	19	0	76	0	0	0	0	0	0	0
1:00	8	0	79	0	0	0	0	0	0	0
1:15	11	1	50	0	0	0	0	0	0	0
1:30	5	0	51	0	0	0	0	0	0	1
1:45	3	0	33	0	0	0	0	0	0	0
2:00	0	0	14	0	0	0	0	0	0	1
2:15	0	0	7	0	0	0	0	0	0	0
2:30	1	0	6	0	0	0	0	0	0	0
2:45	0	0	3	0	0	0	0	0	0	0
3:00	1	0	4	0	0	0	0	0	0	1
3:15	0	0	1	0	0	0	0	0	0	2
3:30	2	0	1	0	0	0	0	0	0	0
3:45	0	0	0	0	0	0	0	0	0	0
4:00	0	0	1	0	0	0	0	0	0	0
4:15	1	0	0	0	0	0	0	0	0	0
4:30	1	0	5	0	0	0	0	0	0	0
4:45	5	1	2	0	0	0	0	0	0	0
5:00	11	1	13	0	0	0	0	0	0	0
5:15	15	0	25	0	0	0	0	0	0	0
5:30	21	1	43	0	1	0	0	0	1	0
5:45	18	1	79	0	0	0	0	0	0	2
6:00	37	2	135	1	4	0	0	0	1	1
6:15	55	0	275	0	7	0	0	0	0	0
6:30	59	4	359	1	8	0	0	0	4	0
6:45	75	5	451	0	11	1	0	0	3	0
TOTAL	25991	407	64177	26	601	8	5	3	852	24