An Assessment of Proposed Bus Rapid Transit (BRT) Peshawar: An Analysis of Modal Shares and Performance Evaluation

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THESIS ACCEPTANCE CERTIFICATE

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DEDICATED
TO
MY LOVING PARENTS, TEACHERS, FRIENDS and MY COLLEAGUES

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Jawad Mehmood

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List of Abbreviations

AVL	-	Automatic Vehicle Location
BCLL	-	Bhopal City Link Limited
BMC	-	Bhopal Municipal Corporation
BRT	-	Bus Rapid Transit
JNNURM	-	Jawaharlal Nehru National Urban Renewal Mission
KPK	-	Khyber Pakhtunkhwa
LRH	-	Lady Reading Hospital
NATO	-	North Atlantic Treaty Organization
PBS	-	Pakistan Bureau of Statistics
PDA	-	Peshawar Development Authority
SC	-	Speed Cycles
SMC	-	Surat Municipal Corporation
T	-	Travel Time
VOC	-	Vehicle Operating Cost

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ABSTRACT

Modal shares of public transport are on continuous decline in many urban areas due to negligence of government and operating agencies, inconvenient and unreliable services which leads to unsustainable development. Therefore, policy makers, stakeholders and government is looking towards more suitable, economic, reliable and convenient service which can mitigate the current issues of congestion, safety and pollution. Bus Rapid Transit (BRT) is an urban transportation scheme that is considered by many countries in public transportation planning now-a-days. It provides comfortable, reliable, and safe services that has a potential to attract significant commuters from private modes to mitigate the problems of congestion, pollution, and traffic accidents. This research is aimed at evaluating the potential of BRT Peshawar to attract commuters pertaining to private modes, and also the comparison of BRT Peshawar with international standards of evaluation. The analysis of modal shares is carried out with the separate binary logit models to model the choices of commuters pertaining to owned car, motorcycle, and taxi towards BRT Peshawar based on identified service attributes that effect the modal shifts. The findings reveal that travel time and vehicle operating cost influence the inter-shifts of private and BRT modes. The travel time significantly affect the modal shifts of motorcycle and taxi users while vehicle operating cost influence more the choice of owned car users. BRT Peshawar has a significant potential to attract commuters of private modes. The shift proportion of taxi users is high as compared to users of car and motorcycle to use BRT as a mode of trip making. This research study has also evaluated BRT Peshawar by comparing it with international standards of BRT "BRT Standards 2016". It was found satisfactory as it meets most of the criteria of international standards, and achieved "Gold Standard BRT" status. However, improvement is needed in some key areas like service planning, infrastructure, and access and integration in which it has scored little low. The policy makers and operating agencies should focus on operating hours, passing lanes, bicycle lanes, and integration of bicycle sharing for increased ridership, service quality and user satisfaction.

CHAPTER 1

1. INTRODUCTION

1.1 Background

Urban transportation schemes are aimed to provide mobility and accessibility to daily commuters in urban areas to assist in sustainable development. Such schemes should have a potential to compel users pertaining to private modes by offering attractive and comfortable services to serve as a backbone for country's development. The goal of it's introduction is to have a reduced travel time based on mass transportation by public modes. It facilitates in reducing pollution and congestion to help in upgrading economy of a country. However, most of the time outcomes of such schemes are not fruitful in meeting the objectives for which it was imposed in developing countries like Pakistan. Modal shifts of public transport are on continuous decline in such countries which can be observed as a result of increase in congestion and pollution. There are multiple reasons behind such a decline in achieving sustainable development in developing countries e.g. inconvenient and uncomfortable services, lack of adherence to schedule, poor transport policies etc. Thus, there is an urgent need that policy makers and stakeholders sit together, and investigate policies, strategies, planning and interventions related to public transport in Pakistan that will assist addressing issues in upcoming projects in zones of China Pakistan Economic Corridor (CPEC) which will help to promote shifts of public transport. In this research study, we have discussed in detail the barriers and strategies that have a substantial impact on influencing modal shifts among private and public mode in one of zone of CPEC, Peshawar city.

World Health Organization (WHO) presented in their report that growing number of deaths borne by vulnerable road users is fuelled by increase in motorized transport in middle- and low-income countries. It is stated that about 1.35 million deaths occur due to road traffic accidents annually and is on continuous increase in middle- and low-income countries. Among different age groups, road traffic accidents are found to be the leading cause of death for children and youngster (5-29 years) while more than half of global deaths are among motorcyclists, cyclists and pedestrians. Road traffic accidents is ranked as eighth (8^{th}) leading category in a list of most dangerous elements causing death and if drastic action would not be taken, the target to halve the road traffic injuries and deaths will not be met by 2020(World Health Organization, 2018). Similar to the world, Pakistan also face same challenges of safety, congestion, and pollution which are directly linked to increase of population and motorization. Pakistan Bureau of Statistics (PBS) stated that population of Pakistan has abruptly increased from 132.35 to 207.77 million (growth rate of 2.4%) in last two decades (Pakistan Bureau of Statistics, 2017b). Moreover, registered vehicles have increased from 6.2 to 21.5 million (growth rate of 14.82%) while accidents increased from 9,496 to 11,121 (growth rate of 1.77%) in a last decade (Pakistan Bureau of Statistics, 2017a, 2018). Such an increase in accidents and motorization depicts that modal shares of public transport are on decline in one of the member of CPEC, which is Pakistan.

Karachi and Lahore are the two main business hubs of Pakistan densely populated having population of 16 and 11.13 million respectively (Pakistan Bureau of Statistics, 2017b). Many urban transport schemes have been initiated in last couple of decades e.g. Omni and Volvo buses in Lahore, and Karachi Circular Railway and Awami Bus Train in Karachi, but it didn't produce fruitful outcomes due to poor service infrastructure and planning, financial losses, and lack of interest of government. Irrespective of introduction of such schemes, Karachi and Lahore pertains modals shares of private and public modes by 27 and 24 percent, and 23 and 16 percent respectively (Imran, 2009). It indicates the decline in public transport use as compared to private modes which depicts the negligence of government in improving policies and strategies to have a sustainable urban development. Additionally, there is a perception that current public modes lack in providing comfortable and timely scheduled services to commuters which has shifted many to private modes (car, jeep and motorcycle) for making journey trips. It resulted in increased pollution and congestion that propagates safety issues which are barriers to the sustainable development. Therefore, government of Pakistan is looking towards safe, high capacity and environmental friendly public mode having advanced technological features which provide comfortable and timely scheduled services at reasonable costs in business hubs of CPEC to achieve sustainable development.

Among different urban schemes, Bus Rapid Transit (BRT) is considered as one of the most economical and viable solution which compensates for the issues of congestion and safety with an increased mobility and accessibility to commuters of all walks of life to have a sustainable urban transportation system. BRT is found to be the low carbon target for Asian countries which will emit less carbon dioxide (CO_2) by compelling users towards it (Kikuchi, Fukuda, Ishizaka, Ito, & Satiennam, 2013; Satiennam, Tankasem, Satiennam, Jantosut, & Detdamrong, 2013). It has become popular worldwide due to service capacity, reduced travel time, relative flexibility, and affordability. BRT projects have proven effective in different parts of world which reduced cost of travel time and traffic fatalities, for example, 142 million USD were saved in travel time reduction from "Metrobus line 3" in Mexico city while 288 and 393 million USD were saved in reduced traffic fatalities/injuries and greenhouse gases in Transmilenio Bogota and Istanbul Metrobus (Carrigan, King, Velasquez, Raifman, & Duduta, 2013). Similarly, BRT project has contributed to reduce air pollution to significant levels e.g. concentration of NO_X was reduced by between 4.7 to 6.5 percent, CO by between 5.5 to 7.2 percent ,and PM_{10} by between 7.3 to 9.2 percent (Bel & Holst, 2018).

The effectiveness of BRT scheme has forced government of Pakistan to consider it's implementation in major metropolitan cities lying in business zones of CPEC to have a sustainable urban development. The government has launched BRT projects in major cities of Pakistan in which the first one has been operational since 2013 at Lahore connecting areas of Shahdara to Gajjumata of length 27km. It bears the highest daily ridership of 179,104 (Punjab Mass Transit Authority). It was found in evaluation study that the metro bus service is satisfactory in all respects including safety, quality, security and reliability. Lahore BRT was evaluated by comparing it with 2014 international standards. It evaluated that BRT Lahore is facing operational and maintenance problems. It failed to achieve Gold, Bronze and Silver and achieved Basic BRT level. It was followed up by Rawalpindi-Islamabad Metrobus which has been in operation since 2015 connecting Saddar to Pak-Secretariat of length 22.5km having average daily ridership of 138,000. Rawalpindi-Islamabad Metro Bus was also evaluated by International BRT Standards 2016. It achieved Bronze BRT criteria which is a higher quality of service and of higher operational efficiency than Basic BRT. Results showed that Rawalpindi-Islamabad BRT does not fulfil the criteria of infrastructure, service planning and integration and access. Subsequently, Multan Metrobus is set operational since 2017 of length 18km having average daily ridership of 97,000 (Farhan Jalil, 2017).

Peshawar is the capital of province of Khyber Pakhtunkhwa (KPK) with a population of 4.26 million in the census of 2017 (Pakistan Bureau of Statistics, 2017b). Peshawar city bears the important geographical location as a business hub which is a gate way to Afghanistan, and connects Central Asian and Middle Eastern states. This business hub holds a geo-strategic position and is a route for North Atlantic Treaty Organization (NATO) supplies (Farooq, Javaid, & Karl, 2015). In a last few decades, private mode of transportation has shown tremendous increase e.g. private cars are increased by 229% in a last decade (Ali, Shah, & Hussain, 2012; Khan & Arshad, 2015; Ullah, Liu, & Vanduy, 2019). Due to such an increase of private modes, the road network of Peshawar city is congested, polluted, and traffic accidents are manipulated which intended government to initiate construction of BRT project in 2017. It has a 26km long corridor having 31 stations with an average distance of 850m between stations, and 15km is at-grade and 8km consists of flyover while the remaining 3km section constitutes of underpass (TransPeshawar).

Evaluation of urban transportation schemes is vital in order to assess the performance and operations as well as to determine the acceptance of such scheme over the daily commuters. The primary concern with BRT Peshawar project is to determine that is the service has a potential to attract commuters from private modes, and to assess the barriers/service attributes that will be influencing the shift of private and BRT modes. Second, is to determine that BRT mode fulfils the international criteria of implementation which will be influencing the ridership and quality of BRT mode that will have an impact on road network parallel to BRT project by reducing congestion, pollution, and traffic accidents issues. These statements provide the basis to conduct a study that will point out the barriers for shifts between modes, and compare it with best international practices that will help to provide mitigation measures accordingly.

This research study aims to evaluate BRT Peshawar by comparing it with international standards and by modal share analysis prior to it's completion. It will evaluate BRT Peshawar by covering each aspect of operational performance and will cover the limitations in previous researches. It will also include binary logit model to determine the modal shares for BRT Peshawar. It will help to determine the modal shares towards Bus Rapid Transit Peshawar by considering some parameters. By making changes in these parameter, modal shifts will be determined towards BRT for these specific values. It will help operating agency to set targets to achieve maximum ridership of BRT Peshawar. By increasing ridership, objective of BRT Peshawar will be completely achieved that will reduce congestion, pollution, fuel consumption, and increase level of service on parallel road of BRT corridor. The first part of the study is on modal shares analysis which is from user perspective on use of BRT while the second part of study is on evaluation of BRT service that whether it fulfils the international standards.

These results can be used to completely evaluate whole BRT Peshawar service. There will be certain limitations and deficiencies in some performance elements which needs to be highlighted. Targets should be set to improve these deficiencies, and parameters values should be set to increase ridership. This will increase overall performance of BRT Peshawar, and fulfil the objective for which it was proposed.

1.2 Problem Statement

Modal shares of public transportation are on decline in most developing countries like Pakistan. Commuters are shifting from public transportation to private owned vehicles which has increased congestion, pollution, accidents, decreased safety of roads etc. The reason behind the shift is that the current public transportation is not achieving the needs the commuters. There are excessive delays, increased travel time, and less comfort in current public transportation system. Hence, there is great need to consider all these problems of commuters/travellers so that people can be shifted back to public transportation to decrease congestion, pollution and fuel.

Government of KPK took initiative in this regard by starting Bus Rapid Transit Peshawar. Construction of BRT Peshawar was started at the end of 2017 which is still in construction phase. It starts form Chamkani and ends at Karkhano Market. It consists of 26km long BRT route which includes 15km at grade, 8km flyover and 3km underpass sections. It has 31 stations and the average distance between stations is 850m. It is expected that BRT Peshawar will attract more commuters towards itself and will decrease congestion on road.

There are several questions which arise that whether BRT will perform well? Will it provide required service to commuters? What are the deficiencies that needs to be addressed? Will there be further improvement needed to increase it’s performance? Will It attract maximum ridership? Which variables will effect modal shares?

These research questions leads to conduct a research study on BRT Peshawar to evaluate it on performance basis as well as to develop a binary logit model to determine the modal share of BRT Peshawar to help agency and decision makers to set targets to improve it's performance.

1.3 Research Objectives

Research objectives are as follows:

- To evaluate BRT Peshawar on various elements for determining the reliability and quality of service.
- To compare BRT Peshawar with International BRT Standards 2016.
- To generate model that will determine modal shifts towards BRT Peshawar.
- To determine deficiencies in various elements of BRT Peshawar and present recommendations.

1.4 Scope of Research Work

This research study will evaluate BRT Peshawar which extends from Chamkani to Karkhano Market. Evaluation of BRT Peshawar is based on performance basis as well as generation of model to determine the modal share of BRT Peshawar in future. Performance evaluation will cover several elements of BRT Peshawar such as service planning, infrastructure, stations, communication, access and integration etc. The scope of this research study is not limited to BRT Peshawar but it provides basis and framework to conduct similar study for other BRT's.

1.5 Organization of Report

This research thesis is divided into five chapters and appendix portion. Each chapter is briefly introduced as follows:

- Chapter 1:
  It gives brief introduction on BRTs and why they are need of present generation. It includes objectives and scope of this research study on BRT Peshawar.

- Chapter 2:

  This chapter is about literature review which provides brief review of past researches on BRTs regarding evaluation of BRT on performance basis and also generation of model to determine shifts towards BRTs.

- Chapter 3:

  This chapter is about methodology of research thesis. It discusses the framework for conduct of this study which includes the detailed survey, formation of questionnaire, site selection, sampling data needed and provides procedure to analyse the collected data.

- Chapter 4:

  This chapter is about the analysis and results of collected data. Analysis is performed on data collected by questionnaire from commuters to generate a model considering different variables to determine modal share of BRT Peshawar. Analysis is also performed on BRT Peshawar by comparing it with BRT standards 2016 which includes some performance indicators like service planning, infrastructure, stations, communication, access and integration etc.

- Chapter 5:

  This chapter is about conclusion and recommendation. Conclusions are drawn from the results of assessment of BRT Peshawar. Recommendations are provided for the improvement of project and helps decision makers and operating agency to set targets for the improvement of the project. It provides recommendations for the future work to be carried either on BRT Peshawar or the other BRT systems.

CHAPTER 2

2. LITERATURE REVIEW

2.1 History of Public Transportation in Pakistan

The history of Public transport in now-existing Pakistan begins since 1861 by building Railway section between Kotri and Karachi. This railway network was later extended by connecting main cities till 1865. Afghanistan border was connected in 1878 and Iran was connected in 1918. In 1885, the first steam run tramway was opened in Karachi along horse drawn tram. In 1908, steam trams were converted to petrol engine. The feeder services and buses were used to support the intercity railway and tramways (Imran, 2009).

In 1947, railway was used as the mean of intercity public transportation. Largest number of passengers were carried by Pakistan Railway (Govt. of Pakistan, National Planning Board 1957). Later on, Omni Bus was started in cities of Karachi and Lahore, while the tramway only provided service in Karachi. The tramway was closed in Karachi in 1970s. In 1960-65, it was planned to include Karachi Circular Railway in plan as the first rail based urban transport project to serve whole Karachi including it's periphery. Later, some sections of Karachi Circular Railway(KCR) were built. KCR was successful during 15 years but later it declined due to lack of attention and investment. In 1977, Punjab Urban Transport Corporatiom (PUTC) and Punjab Road Transport Corporation were established in Punjab. Their function was to provide economical, efficient, and adequate road based service in intercity and urban public transport system. Due to lack of buses, Omni buses were merged in PUTC. Swedish Government gifted 350 Volvo buses and these were added to PUTC. PUTC was collapsed after the operation of several years due to lack of funds and Government closed it in 1998 (Imran, 2009).

A draft National Transport Policy was made by NTRC which suggested bus based transportation as compared to rail based public transportation for the metropolitan cities in Pakistan. In 1991, Nawaz Sharif's government started Prime Minister's Incentive Scheme to upgrade public transport. This scheme included the duty free import of buses, taxis and mini buses. This policy upgraded the public transport but the policy was changed after Nawaz government (Imran, 2009).

In 1989, Awami Bus Train was started by Ms. Bhutto in Rawalpindi, Islamabad and Karachi. This system comprised of the prime mover with three trailers to provide high capacity during peak hours. This bus service attracted large number of passengers in Islamabad and Rawalpindi. 68% of the it's cost was recovered during first two years from fares. This service was later closed due to lack of interest of government (Imran, 2009).

In 1996, Prime Minister Benazir Bhutto started mass transit project in cities of Islamabad and Rawalpindi which was based on road-rail mixed mode. This system connected Rawalpindi and Islamabad by rail link with feeder buses. This was initiated to reduce pollution, congestion and to use already existing railway. That train was designed to carry 6,000 to 8,000 passengers per day. This train service was later shut down due to poor service planning and financial losses (Imran, 2009).

Then there came the era of BRTs. Operation of Lahore BRT started in February 2013 to provide efficient, safe, comfortable and economical journey. It operates between Shahdara and Gajjumatta which is 27km long route which consists of 8.3km elevated section, and have a daily ridership of 179,104 (Punjab Mass Transit Authority). It consists of 64 articulated buses with the seating capacity of 38 passengers. Bus can carry maximum passengers upto 160. The total travel time through BRT Lahore is 63 minutes between Shahdara and Gajjumatta (Ahmed & Azeem, 2015).

Lahore BRT was followed by Islamabad-Rawalpindi Metro Bus in June, 2015. Islamabad-Rawalpindi is a 22.5km long which runs between Pak Secretariat and Rawalpindi Saddar. The average daily ridership of Islamabad-Rawalpindi Metro Bus is 138,000. After that Multan Metro Bus Service was started in January, 2017. Multan Metro Bus is 18km long route which operates between Kumharanwala Chowk and Bahauddin Zikriya University. The average daily ridership of Multan Metro Bus is 97,000 (Farhan Jalil, 2017).

After that, construction of BRT Peshawar was started in 2017 which is in progress. It starts form Chamkani to Karkhano Market. It consists of 26km long BRT route which includes 15km at grade, 8km flyover and 3km underpass section. It has 31 stations and the average distance between stations is 850m. It has 5 feeder routes. It has 3 park and ride facility, and 3 bus depots (TransPeshawar).

2.2 Mass Transit System

Mass transit system helps in the efficient movement of large groups of people within metropolitan areas from one point to another in lesser time with reduced travel costs using trains, subway trains, buses etc. They are broadly categorized as bus and rail systems including Inter-city rail, high speed rail, Maglev, light rail, medium capacity rail system, monorail, rapid transit, tram-train, articulated bus, metro, commuter rail etc.

2.3 Bus Rapid Transit (BRT)

Fielding, Babitsky, and Brenner (1985) defined Bus Rapid Transit as “Rapid transit is not a transport mode as such, but it is means of mass transportation offering a faster service than the alternatives which are available, typically with average operating speeds of 50 kmph or more which generally requires exclusive rights of way. Rapid transit services are commonly provided by light rail, but certain heavy rail systems also fall into this category. Guiding bus services which operate on dedicated rights-of-way and which are therefore faster than those sharing road spaces with other traffic. BRT is a flexible, high performance rapid transit mode that combines a variety of physical, operating and system elements into a permanently integrated system with a quality image and unique identity”.

Agarwal, Anupama, and Singh (2010) defined BRT as “Bus Rapid Transit System (BRTS) is an innovative, high capacity, lower cost public transport solution that can significantly improve urban mobility”

Ibtishamiah, Adji, and Karim (2013) defined BRT as “Bus Rapid Transit gives communities the best bang for their buck when it comes to investing in transit. This new system will better connect workers to jobs, shoppers to stores and Oregon to the rapidly growing economy.”

2.4 BRT Benefits

Agarwal et al. (2010) overviews bus rapid transit system that Bus Rapid Transit System is a lower cost and high capacity public transport system that improves urban mobility. Bus Rapid Transit System is generally less costly to build than rail transit. BRTS is the convenient and cost effective way of transport in urban and suburban environments. Bus

Rapid Transit System can provide high transport capacity with good quality. Bus Rapid Transit System can utilize vehicles from standard buses to special vehicles. ITS technologies can be integrated into Bus Rapid Transit System to improve it's performance in terms of reliability, travel time, convenience, efficiency, security and safety. It can help in making a service plan that fulfil the needs of the employment centres and population. BRT uses exclusive travel ways so that the person minutes saved is more than the person minutes lost by people in automobiles which means that travel time is significantly reduced.

2.5 Past Researches on BRT

Rathore and Ali (2015) evaluated Lahore Bus Rapid Transit System on basis of 2014 BRT Standards and compared various elements of BRT Lahore with international standards of BRT 2014 to evaluate the performance of BRT Lahore. Lahore BRT failed to achieve Gold, Bronze and Silver, and achieved Basic BRT level. They also evaluated that deviations from transport policies and studies conducted by JICA leads to failure of transport system in Lahore, and found out that the Lahore BRT is facing operational and maintenance problems.

Jalil (2017) evaluated Rawalpindi-Islamabad BRT on basis of BRT Standards 2016 and compared various elements of BRT Rawalpindi-Islamabad with international BRT standards 2016 and evaluated performance of Rawalpindi-Islamabad Metro Bus. Rawalpindi-Islamabad achieved the Bronze BRT criteria. They evaluated that Rawalpindi-Islamabad BRT does not fulfil the criteria of infrastructure, service planning and integration and access.

Chaurasia (2014) investigated the properties and various features of Bus Rapid Transit System with help of already operating various BRT. He took the case study of Bhopal to analyse the conditions of BRT. BRT System of Bhopal was funded under scheme of JNNURM by central government and was constructed by BMC and is operational under BCLL. It passes through market areas and main city and is supported by standard, trunk, complimentary and intermediate para transit routes. Mini Buses and Magic provide transport services from residential areas to BRT routes. Bhopal BRT also identified as MYBus, connects different city parts of the city with 24km route and consists of 82 bus stops. BRT users are around 45,000 daily and BRT users are expected to increase to

100,000 by next year. Therefore, the operating agency of BRT 'BCLL' proposes Articulated Buses to cater for future demand. He studied that more than half of the BRT corridor infrastructure is in poor condition and there is lot to do in public information system, foot over bridges, safety concerns of pedestrians etc. According to his survey, 100% users of BRT showed positive response towards BRT in Bhopal as future need. He concludes that BRT provides comfortable and safe corridor for motor vehicles, pedestrians, cyclists etc. with the important elements as public information system, pedestrian crossing signals, curbs, platform, pedestrian subways, bus stops, foot over bridges, railings, signage and road markings etc and should be user friendly and there should be accommodation for physically impaired persons so that everyone can use it.

Ahmed and Azeem (2015) studied performance evaluation of metro bus Lahore which is 27 km long corridor with 27 stations and the average daily ridership of 125,000. Performance evaluation was assessed on basis of productivity, service frequency, product capacity, safety, utilization and service provided. Information was collected from different surveys, interviews and metro bus authority to evaluate the performance of metro bus Lahore. They did the analysis of headway, accidents, frequency, passenger boarding, reliability, transit availability, transit quality to assess performance of Metro Lahore. They evaluated that the metro bus service is satisfactory in all respects including safety, quality, security and of good reliability.

Panchore and Khushwaha (2016) defined BRT as faster mode of mass transportation than other available modes with 50kph or more average operating speed. According to him, exclusive right of way is required for rapid transit. Rapid transit is faster mode as compared to those sharing road. BRT is a rapid transit mode with high flexibility and performance and it combines different system, operating and physical elements into integrated system that provide high quality and reliable service. BRT is lower cost and high capacity service that can increase mobility.

Rahul and Kasundra (2017) did a review study on Performance evaluation of BRT Transit System. According to them, BRT offers a flexible, clean, safe, innovative system, affordable, economical, cost effective and simply accessible with high mobility that can improve quality service in urban areas. He did study of performance evaluation of BRT for India using different on board surveys like delay time, public opinion, travel time, passenger frequency surveys. They studied Janmarg, Ahmadabad BRTS in which 5 corridors were selected in which parameters studied are environmental, social and traffic impacts. They studied that average speed is increasing, congestion is decreased and composition of pollutants is decreasing along corridors due to BRT implementation. They also studied performance evaluation of Ambedkar to Moolchand corridor of Delhi BRT on the basis of different surveys including queue length, pedestrian volume count, volume study at intersections, occupancy surveys, spot speed studies, speed studies, delay studies, parking surveys, fuel consumption, opinion surveys, and analysis to allow other vehicles to move on BRT lane. The parameters used for performance were passenger flow, modal split, traffic flow, road crash, corridor ratings by user etc. From results, it was clear that non-BRT section carry comparable flows of traffic, and passenger load as compared to non-BRT is higher on BRT routes. In mixed traffic, passenger share is better in case of non-BRT condition. There is average speed increase of 3% on BRT route. The corridor was rated between bad to average before BRT scenario and now it Is rated between average to good. Accidents are increased and average queue length increased after implementation of BRT.

Hidalgo and Pai (2010) evaluated Delhi bus corridor, and conducted an independent evaluation on basis of technical arguments to this discussion to provide recommendations for the improvement of corridor. The authors conclude that the Delhi bus corridor has improved mobility of people. Speeds of buses are 150% faster than buses outside the corridor which results in the reduction of travel time along the corridor of 19% for all commuters and obtained high ratings from the users. Travel experience was improved by having facilities for pedestrians and bicycles but requires significant safety, performance and overall quality enhancements. The project only comprised major changes in infrastructure but lacked in integrated implementation of service plans, technologies and operations. Education of community and users was also not satisfactory.

Jaiswal, Sharma, and Krishnan (2002) studied the impact of BRT System on Ahmadabad's transport sector and analysed the changes that can be made by introduction of Bus Rapid Transit System in other cities of India. They evaluated that Bus Rapid Transit System of Ahmadabad has improved access for local riders while reducing the environmental impacts of transportation. They also discussed the characteristics of Bus Rapid Transit System like provision of dedicated lanes and frequency of operations etc. BRT has greater flexibility as compared to light rail. They took a case study of Janmarg Bus Rapid Transit System, Ahmadabad. There is proper feeder system in Janmarg which feeds people to BRT. They identified various parameters as Social impacts, Traffic impacts and Environmental impacts. The traffic is flowing freely which increases the average speed along the corridor. Users are satisfied by the BRTS as identified by user rating analysis. Congestion is significantly decreased along BRT corridor due to implementation of BRT. There is significant reduction in composition of pollutants along BRT corridor. There is great shit of private vehicles to public transport mode.

Velmurugan et al. (2012) analysed the performance evaluation of Ambedkar to Moolchand corridor of Delhi BRT on the basis of different surveys including queue length, pedestrian volume count, volume study at intersections, occupancy surveys, spot speed studies, speed studies, delay studies, parking surveys, fuel consumption, opinion surveys, and analysis to allow other vehicles to move on BRT lane. The parameters used for performance were passenger flow, modal split, traffic flow, road crash, corridor ratings by user etc. It was found that non-BRT section carry comparable flows of traffic while passenger load on BRT Is high. In mixed traffic, passenger share is better in case of non-BRT condition. There is average speed increase of 3% on BRT route. The corridor was rated between bad to average before BRT scenario and now it Is rated between average to good. Accidents are increased and average queue length increased after implementation of BRT.

GANDHI, TIWARI, and FAZIO (2013) on their study of "Comparative Evaluation of Alternate Bus Rapid Transit System (BRTS) Planning, Operation and Design Options" studied alternate operation, planning and design options for BRTS. In this study, spreadsheet tool is used to develop performance results for various indicators of different design and planning purposes. Two standard designs in varying context, two currently operational design variations and Sixteen theoretical configurations are compared. Results show that bus operational speeds are 25% less in open system than in closed system. Speed for the trip length of less than 10km in open system is higher for passengers than closed bus operations. By restricting peak speed of bus to less than 40kph for safety purposes does not alter passengers or operational performance.

Seraj, Hadiuzzaman, Hasan, and Musabbir (2015) did analysis of commuter preferences to proposed bus rapid transit system in Dhaka. They studied the distribution of respondents for existing modes by gender, age, monthly income and occupation. About 69% of respondents were male, 11.25% of respondents were of more than 45 year age, 44.73% of respondents were between 30-45 years age, 44.01% of respondents were between 14-30 years age. 18.45% of respondents were of business class, 57.16% were job holders and 24.39% were students. Logit models were developed to find the commuter preferences between the existing modes and the proposed Bus Rapid Transit by finding utility of modes. Revealed and stated preference approaches were introduced in the survey. Surveyed was conducted from passengers in form of questionnaire to get real time data, and asked about their preferences about the hypothetical scenario. Binary logit models were introduced for commuter choices between existing and proposed mode. Separate models were generated for bus, car, CNG run auto rickshaw, rickshaw with BRT that predict the modal shifts between existing and proposed BRT mode. BRT is preferred by young and low income bus riders, and female, students and job holder rickshaw riders. BRT is less preferred by the young and low and medium income users of rickshaw. Increase in travel time reduces the potential of BRT to attract users towards it.

Kumar and Electricwala (2014) performed a study to determine modal shifts from private users to proposed BRT in Surat, India. The municipal area of Surat is 312 Sq.km having a population of 2.4 million according to 2001 census. Seven corridors were proposed and one of them was selected for study known as Dumas resort canal- road having a length of 23.5km. A combination of stated preference and revealed preference survey of 1250 commuters was conducted to determine travellers present preferences and future preferences to shift towards BRT. Binary logit analysis was adopted to determine the utility functions for model generation. SPSS and Biogeme procedures were used to estimate the models. Five modes were selected for analysis namely car, shared auto, two wheeler, bicycle and local bus. t-statistic for constant and all attributes was more than 1.96 which indicates good results. SPSS shows a shift of 37.38% and Biogeme shows a shift of 45.46% from two wheelers towards BRT. Shifts from shared autos towards BRT was estimated to be 87.40% and 80.58% for Biogeme and SPSS model respectively. Shifts from cars towards BRT was calculated as 11.49% and 6.78% for Biogeme and SPSS model respectively. Shifts of Bus towards BRT was calculated as 85.16% and 71.99% for Biogeme and SPSS model respectively. Shifts for bicycle towards BRT was calculated as 64.91% and 55.87% for Biogeme and SPSS model respectively. SPSS analysis shows that 42.1% of the commuters are going to shift towards BRT while Biogeme analysis shows that 49.07% of the commuters are going to shift towards BRT.

This study also revealed that users of SMC bus and shared autos have showed willingness of 78.575% and 84% towards BRT.

Satiennam, Jaensirisak, Satiennam, and Detdamrong (2016) did a study on potential of modal shifts of motorcycle and passenger car users towards BRT. Khon Khae city was selected for case study in Thailand. It has 51% of trips by motorcycles and 30% by passenger cars. There are less than 20% of trips by existing public transportation pickup truck Song Thaew because of it's unpunctual, delayed, uncomfortable service. There is plan to start five lines of BRT in Khon Khae city. The BRT line on it's main corridor of Friendship Highway is known as Red line is selected for study having a length of 30km and 17 stations. Stated preference approach was adopted for the conduct of survey. Binary logit model was used for the determination of modal shift. Sample collected is comprised of 59% male users and 41% female users of passenger cars. There are 47% male and 53% female users of motorcycles. It is observed that average income of motorcycle users is 8400 Baht per month which is lower than passenger car users which is 20,200 Baht per month. The model generated has the negative signs for the coefficient of travel cost and travel for BRT, motorcycle and passenger car which shows that the preference will be decreased with the increase in travel cost and travel time. The sign for the coefficient of age of motorcycle users is positive which shows that old users of motorcycle are more likely to shift to BRT as compared to young users. The sign for coefficient of gender of motorcycle user is positive which shows that female users are more likely to shift towards BRT. The sign for coefficient of driving licence for passenger cars is negative which shows that users without licence will shift towards BRT. Private vehicle users having residential location of 400 m are willing to shift as compared to those having location farther than 400m from station. Analysis showed that travel cost and travel time affects modal shifts. According to results, motorcycles users are more likely to shift towards BRT as compared to passenger car users.

CHAPTER 3

3. METHODOLOGY

3.1 Introduction

This chapter explains the methodology used to carry out the research thesis based on evaluation of BRT Peshawar. It discusses the framework for conduct of this study which includes the detailed survey, formation of questionnaire, site selection, sampling data needed and provides procedure to analyse the collected data. It helps to provide framework for the conduct of field and office study. Office study is carried out to provide framework for the formation of questionnaire, interview questions, commuter survey, route survey data needed etc. to meet the objectives the objectives of this research study. Detailed literature review is carried out for this purpose. After office study, field study is conducted. The data is collected from interview of personnel of TransPeshawar department, passengers and drivers on basis of questionnaire, route survey etc. This data is then analysed for the generation of results.

3.2 Research Methodology

Research methodology for this research study is shown with the help of flow chart as shown in Figure 3.1. Detailed literature review helps to formulate steps for the conduct of study. Literature review is conducted by studying various performance and modal share evaluation studies on BRTs either in running state or proposed. This helped a lot to develop complete framework to carry out this study. Literature review is followed up by data collection. Data collection is divided into two phases i.e. primary and secondary data collection. Primary data is collected directly from commuters through questionnaire and route survey. Secondary data is collected from department of Transpeshawar.

Data collection leads to data analysis where the raw data is analysed to get the results for evaluation of this study. Analysis is performed by development of separate models between each of three private modes (car, taxi, and motorcycle) and BRT Peshawar mode which will determine modal shares. The proposed unbiased model constructed was based on revealed and stated preference survey in order to correctly model the commuters current modal choices and their willingness to shift to proposed BRT. Binary logit model was introduced to model the commuter preferences on service attributes of current modes and BRT Peshawar. The polynomial utility function was derived as result of binary logit model which is used to predict shifts between current modes and the BRT Peshawar to make a journey trip. The difference between service attributes of current mode and BRT will predict the modal shifts between two modes. Eq. (3.1) can be used to determine shifts between two selected modes. Binary logit function is given in below Eq. (3.1) (Sinha & Labi, 2011)

$$P_{BRT} = \frac{e^{U_{BRT}}}{e^{U_{BRT}} + e^{U_m}} = \frac{1}{1 + e^{U_m - U_{BRT}}} \tag{3.1}$$

Where,

U_m = Utility or satisfaction of choice m

U_{BRT} = Utility or satisfaction of BRT

P_{BRT} = Modal shift towards BRT Peshawar from mode m

Service attributes which are selected for modelling binary logit model includes travel time, speed cycles, and vehicle operating cost. The polynomial utility function with the difference in service attributes of current mode and proposed BRT Peshawar is given below in Eq. (3.2)

$$U_m - U_{BRT} = \Delta\beta_0 + \beta_1(T_m - T_{BRT}) + \beta_2(SC_m - SC_{BRT}) + \beta_3(VOC_m - VOC_{BRT}) \tag{3.2}$$

Eq. (3.2) can be simplified as in Eq. (3.3)

$$\Delta U = \Delta\beta_0 + \beta_1\Delta t + \beta_2\Delta SC + \beta_3\Delta VOC \tag{3.3}$$

where,

T_m = Travel time of mode “m” (min per km)

T_{BRT} = Travel time of BRT (min per km)

SC_m = Speed cycles of mode “m” per km

SC_{BRT} = Speed cycles of BRT per km

VOC_m = Vehicle operating cost of mode “m” (cents per vehicle per km)

VOC_{BRT} = Vehicle operating cost of BRT (cents per vehicle per km)

β_0 , β_1 , β_2 , β_3 = Coefficients of service attributes

This research has also evaluated the BRT Peshawar by comparison with the "BRT Standards 2016". The elements on behalf of which the evaluation is carried out are: BRT basics, service planning, infrastructure, stations, communications, and access and integration which are further sub-categorized. The data was collected from field visits and TransPeshawar department which assisted to carry out evaluation.

3.3 Questionnaire Form

Most important element of any research study is data. For analysis purpose, data is needed and results are extracted from analysis. It is very important to know that which type of data is needed for analysis and how should it be collected. Data is divided into two types i.e. primary data and secondary data. Primary data is the one which is collected by researcher himself. It includes questionnaire survey, interviews from commuters, experiments etc. It is collected from sample of population. While the secondary is the data collected from the departments who have already collected data.

For this research study, primary data is collected by questionnaire survey and route survey. Questionnaire should include all questions required to collect data from commuters. It should be well designed so that respondent feel easy to answer questions. The questions asked should be in sequence and there should be an ordered flow. It was tried hard to make questionnaire in which the questions asked are easy to understand and there is kept an order flow of questions. It included the basic information of respondent, travel time, speed cycles, modal shift data.

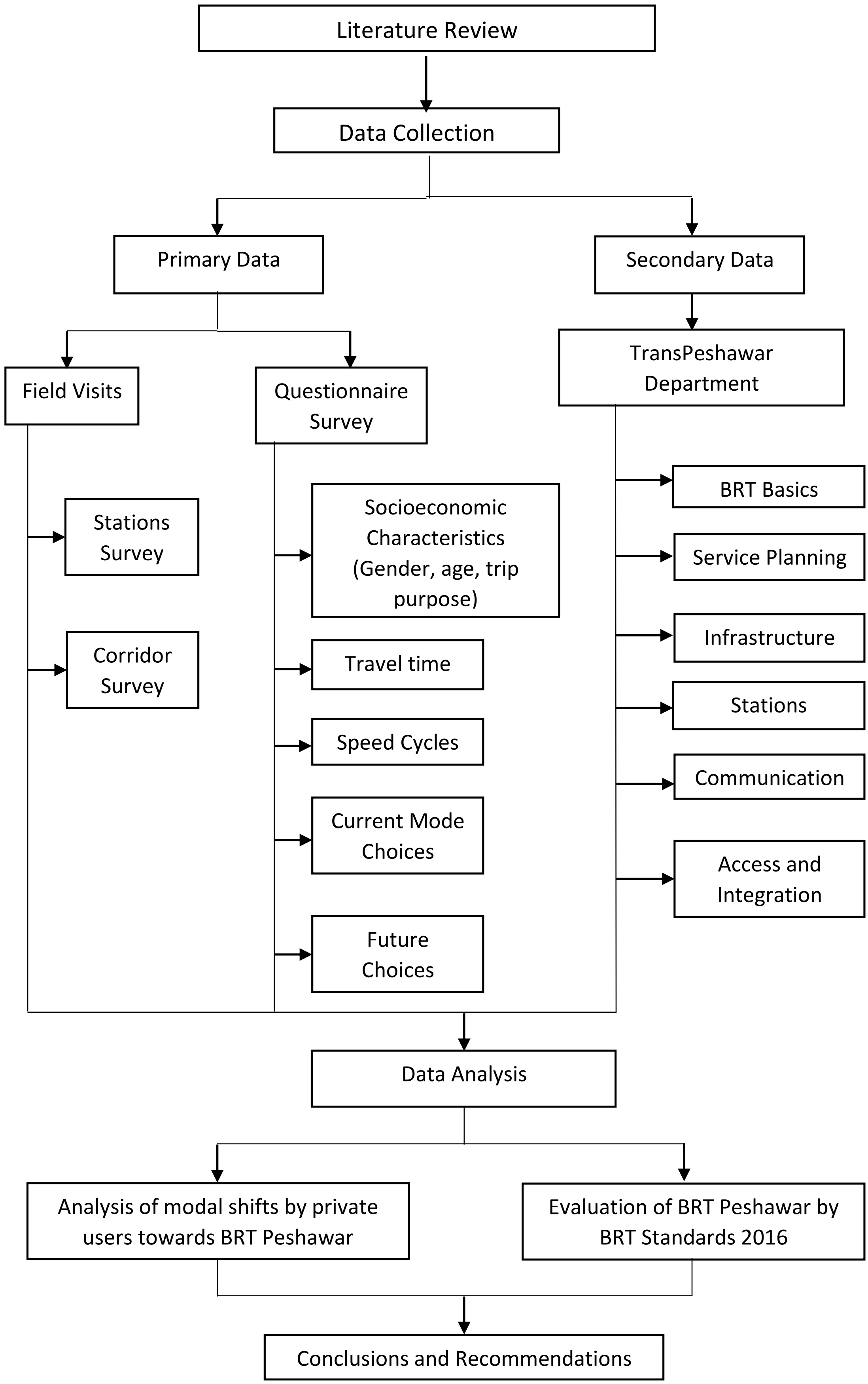

Figure 3.1 Framework for Research Study

3.4 Data Collection

Data is the important and basic need of any research project to be carried out. Data collection is the process in which data is collected from different sources, grouped and organized so that it can be useful for the researcher to carry out analysis on this data to extract results. Care should be taken while collecting data so that correct data can be collected. Correct data leads to correct results that will help to make true conclusions and recommendations. Data for proposed BRT Peshawar is collected in two phases i.e. Primary data and secondary data which are explained as below.

3.4.1 Primary Data

Primary data is one which is collected by the researcher himself through questionnaire and interviews of commuters/respondents, experiments, field visits etc. In this research study, questionnaire survey was adopted to collect the primary data from the commuters of public transportation as well as private owned vehicles. Survey team was selected for this purpose to collect data. Survey team visited BRT Peshawar corridor and stations to collect data for pre-performance evaluation. Survey team also conducted questionnaire survey form commuters of parallel road to collect data for basic information of driver and passenger, travel time, speed cycles, their preferred mode in future. The data for parallel road to BRT Peshawar was collected by questionnaire survey from commuters.

Data collected from primary sources was also used for performance evaluation of Bus Rapid Transit Peshawar by comparing it with BRT standards 2016 by considering different elements. Data collected from questionnaire survey was used to generate three binary logit models on the basis of three variables i.e. travel time, speed cycles and vehicle operating costs. Three separate binary logit models were developed between each three private modes (car, taxi, motorcycle) and BRT Peshawar mode. Questionnaire survey data also determine the shifts of commuters from current used vehicles towards BRT Peshawar in future.

3.4.1.1 Sample Size

Data is basic element of any research project but when the data is to be collected from population, it is very difficult to consider each entity of population as population is either of city, province, country etc. So, it is not feasible to survey and collect data from whole population. There is process called sampling is used in which small proportion is taken from whole population to make inferences about population and extract results. Population includes each entity while sample is some part of population which is truly representative of population. Sampling should be random and there should be the equal chance for each entity to be selected.

Most important part of sampling is the size of sample. Sample size should be suitable so that it can truly represent population and make inferences about whole population. If the sample size is not suitable, it will be deficient to extract results about the whole population. It will either over or under estimate the population. So, it needs to be calculated properly to make it fair and suitable one.

To calculate fair and suitable sample size, literature study was carried out. Dr. Dillman study was found suitable in this regard. He gave the following formula to calculate sample size as shown in Eq. (3.4)

$$N_s = \frac{(N_p)(p)(1-p)}{(N_p-1)\left(\frac{B}{C}\right)^2+(p)(1-p)} \tag{3.4}$$

where,

N_s = Required sample size

N_p = Population size

C = Z statistic associated with confidence interval. It is 1.645 for confidence level of 90%, 1.960 for confidence level of 95% and 2.576 for confidence level of 99%.

P = Expected proportion which answer. 0.5 or 50% is used.

B = Sampling error. For sampling error of $\pm$ 5%, B value of 0.05 is used. For sampling error of $\pm$ 3%, B value of 0.03 is used.

By using above formula, sample size (N_s) was calculated which came out to be 384 for the population (N_p) of 4,269,079. Confidence interval was taken as 95% and p value was taken as 0.5. B value for sampling error was taken as 0.05. The survey comprised of 1776 sample size in which 420 sample was collected for each mode including car, motorcycles, taxi, bus while the data of other modes consists of 96 samples. Once sample size was determined, next step was to select the sites/sections of BRT Peshawar for conducting questionnaire survey.

3.4.1.2 Selection of Sites/Sections

Site selection is very important for questionnaire survey that where the survey should be done. So, it needs to be selected for fair data collection. BRT Peshawar is 26km long which extends between Chamkani and Karkhano. Route survey was done by team for whole BRT Peshawar for evaluation by comparing it with BRT standards 2016. But it is very difficult to conduct a questionnaire survey on whole BRT Peshawar. For that purpose, six sections of BRT Peshawar were selected regarding which the survey was conducted. These six sections are parallel to BRT and respondents were asked to answer questions about their travel time, speed cycles, mode of travel, purpose of trip and their preferred mode in future. Those six sections selected are as follows:

- Karkhano Station to PDA Station or vice versa (2.8 km)
- Tatara Park Station to Board Bazar Station or vice versa (3.7 km)
- Board Bazar Station to Peshawar University Station or vice versa (1.5 km)
- University Town Station to Tehkal Station or vice versa (2.3 km)
- Tehkal Station to Saddar Station or vice versa (3.7 km)
- Malik Saad Station near LRH to Old Haji Camp Station or vice versa (2.9 km)

Survey was conducted at stations, route parallel to above six sections of BRT Peshawar. To carry out fair questionnaire survey, questions were asked from drivers, passengers, gender and different age groups.

3.4.2 Secondary Data Collection

Secondary data consist of that data which is not directly collected by the researcher himself rather it is collected by someone else. Secondary data is obtained from different sources such as departments, newspapers, journals, reports of different organizations or institutions etc. The basic advantage of secondary data is that it is available in processed form and it helps to analyse data easily. It saves cost and time as compared to primary data as it involves surveys, data collection, arrangement etc.

Secondary data for this research study was collected from different departments including MMP and TransPeshawar departments. The data collected is comprised of data regarding stations, buses, pavement quality, passing lanes, technology used in buses for emission control, number of buses, type of buses, average speed of buses, buses stop time, frequency of buses, headway time etc. This data is analysed to compare with international policy of BRT standards to evaluate BRT Peshawar.

CHAPTER 4

4. ANALYSIS AND RESULTS

Bus Rapid Transit (BRT) is considered as one of the most economical and viable solution which compensates for the issues of congestion and safety with an increased mobility and accessibility to have a sustainable urban transportation system. However, evaluation of such scheme is vital in order to assess the performance and operations as well as to determine the acceptance of the scheme over the daily commuters. The primary concern with BRT Peshawar project is to determine that is the service has a potential to attract commuters from private modes, and to assess the barriers/service attributes that will be influencing the shift of private and BRT modes. Second, is to determine that BRT mode fulfils the international criteria of implementation which will be influencing the ridership and quality of BRT mode. These statements provide the basis to conduct a research study on modal share analysis, and evaluation of BRT Peshawar buy comparison with international standards of BRT Standards 2016. This research study has carried out analysis on modal shares and compared BRT Peshawar with BRT Standards 2016 which are discussed in detail.

4.1 Modal Shifts Analysis of Private Users towards Proposed BRT Peshawar

Data is the important element in any research study to analyse and extract outcomes based on data collected through survey to evaluate the study. The data was collected in form of questionnaire survey from daily commuters (car, motorcycles, taxi, and bus) at locations (bus stops, taxi stops, university and BRT stations) near to study area aforementioned in methodology. Questionnaire survey was comprised of revealed preference and stated preference survey. Respondents were asked about socio-economic characteristics (gender, age, trip purpose, travel time, speed cycles), and current mode of travel in revealed preference survey while in stated preference survey, commuters were presented choices where they have to select between current modes and proposed BRT. The data of speed cycles was collected from drivers of respective modes, and the vehicle operating cost of motorcycle users was achieved from drivers. The vehicles operating cost for car, taxi, and BRT bus was calculated using Hepburn model from known speeds. The data including speed and speed cycles of BRT was retrieved from TransPeshawar department which is responsible to operate and manage BRT project. The survey comprised of 1776 sample size in which 420 sample was collected for each mode including car, motorcycles, taxi, bus while the data of other modes consists of 96 samples.

The proposed unbiased model constructed is based on revealed and stated preference survey in order to correctly model the commuters current modal choices and their willingness to shift to proposed BRT. Separate binary logit models are introduced for three modes (car, taxi, and motorcycle) to model the commuter preferences on service attributes of current modes and BRT Peshawar. The polynomial utility functions are derived as result of binary logit model which is used to predict shifts between current modes and the BRT Peshawar to make a journey trip. The difference between service attributes of current mode and BRT will predict the modal shifts between two modes. Eq. (4.1) can be used to determine shifts between two selected modes. Binary logit function is given in below Eq. (4.1)

$$P_{BRT} = \frac{e^{U_{BRT}}}{e^{U_{BRT}}+e^{U_m}} = \frac{1}{1+e^{U_m-U_{BRT}}} = \frac{1}{1+e^{\Delta U}} \quad (4.1)$$

Where,
U_m = Utility or satisfaction of choice m
U_{BRT} = Utility or satisfaction of BRT
P_{BRT} = Modal shift towards BRT Peshawar from mode m

Service attributes which are selected for modelling binary logit model includes travel time, speed cycles, and vehicle operating cost. The polynomial utility function with the difference in service attributes of current mode and proposed BRT Peshawar is given below in Eq. (4.2)

$$U_m - U_{BRT} = \Delta\beta_0 + \beta_1(T_m - T_{BRT}) + \beta_2(SC_m - SC_{BRT}) + \beta_3(VOC_m - VOC_{BRT}) \quad (4.2)$$

Eq. (2) can be simplified as in Eq. (3)

$$ln(\frac{1-P_{BRT}}{P_{BRT}}) = \Delta U = \Delta\beta_0 + \beta_1\Delta T + \beta_2\Delta SC + \beta_3\Delta VOC \quad (4.3)$$

where,
T_m = Travel time of mode “m” (min per km)
T_{BRT} = Travel time of BRT (min per km)
SC_m = Speed cycles of mode “m” per km
SC_{BRT} = Speed cycles of BRT per km

VOC_m = Vehicle operating cost of mode "m" (cents per vehicle per km)
VOC_{BRT} = Vehicle operating cost of BRT (cents per vehicle per km)
β_0 , β_1 , β_2 , β_3 = Coefficients of service attributes

The socioeconomic characteristics (gender, age, trip purpose), travel time, speed cycles, and vehicle operating costs of the data are discussed in detail below. The model estimation results are also found out and are presented below.

4.1.1 Gender

The distribution of gender is shown in Table 4.1 which is clearly represented in Figure 4.1. The male and female data is incorporated because Peshawar city has the special norms and traditions in which female are given separate seats from male so, it is necessary to know that what are the proportions of male and female, and how much male and female will be shifted from current modes towards BRT service for providing spaces for female in accordance. The total sample collected is 1776 in which male and female consists of 1336 and 440 respectively. It shows that male and female respondents are 75.23 and 24.77 percent respectively in which male proportion is high as compared to female respondents.

Table 4.1 Gender distribution

Gender	Respondents
Male	1336
Female	440
Total	1776

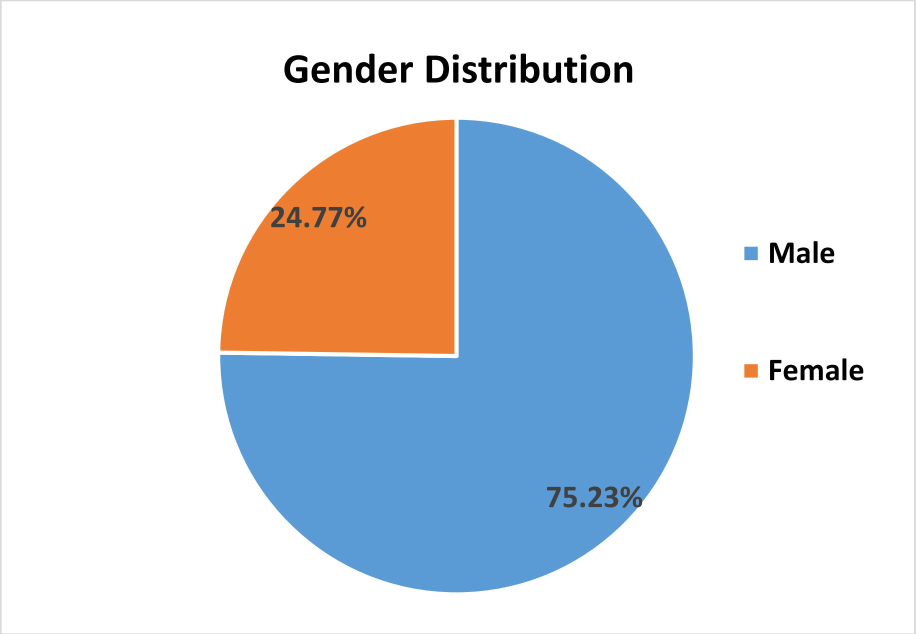

Figure 4.1 Gender Distribution

The sample contains 764 drivers while 1012 passengers which are shown in Table 4.2 and represented in Figure 4.2. The figure depicts that passengers are more as compared to drivers.

Table 4.2 Drivers/Passengers

Drivers/Passengers	Respondents
Drivers	764
Passengers	1012
Total	1776

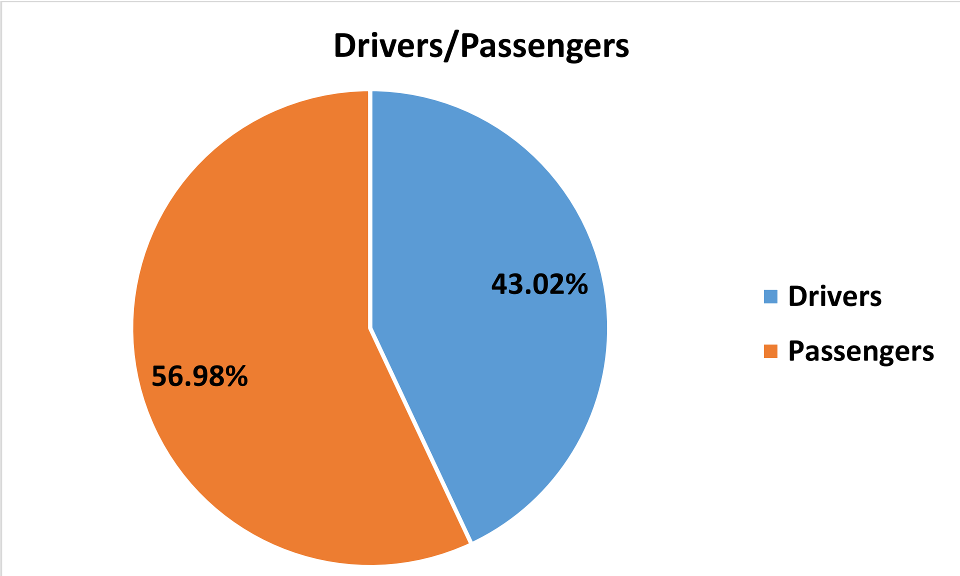

Figure 4.2 Representation of Drivers/Passengers

The drivers are further distributed into male and female drivers which constitutes 696 and 68 of the sample respectively. The male and female drivers are categorized into five categories which includes car, motorcycle, taxi, bus, and other modes. The driver respondents are shown in Table 4.3. The proportions of drivers pertaining to current modes are represented in Figure 4.3 with the inner doughnut showing female proportions while the outer doughnut represents male proportions out of 764 drivers.

Table 4.3 Representation of mode choice by drivers

Mode	Female Drivers	Male Drivers
Car	68	276
Motorcycle	0	420
Taxi	0	0
Bus	0	0
Other	0	0
Total	68	696

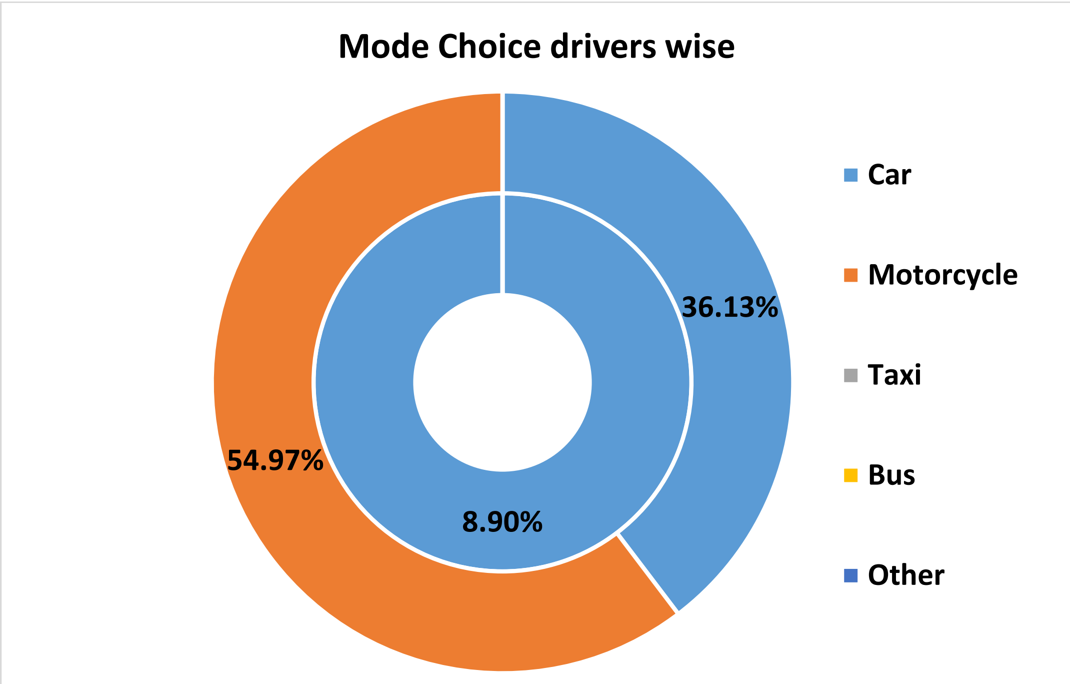

Figure 4.3 Representation of mode choice by drivers

The passengers are distributed into male and female passengers which consists of 640 and 372 respondents of the sample. These passengers are further categorised into five categories as shown in Table 4.4. The proportions of male and female passengers pertaining to current modes are represented in Figure 4.4 with the inner doughnut representing female proportions while outer doughnut represents male proportions out of 1012 respondents.

Table 4.4 Representation of mode choice by passengers

Mode	Female Passengers	Male Passengers
Car	58	18
Motorcycle	0	0
Taxi	144	276
Bus	124	296
Other	46	50
Total	372	640

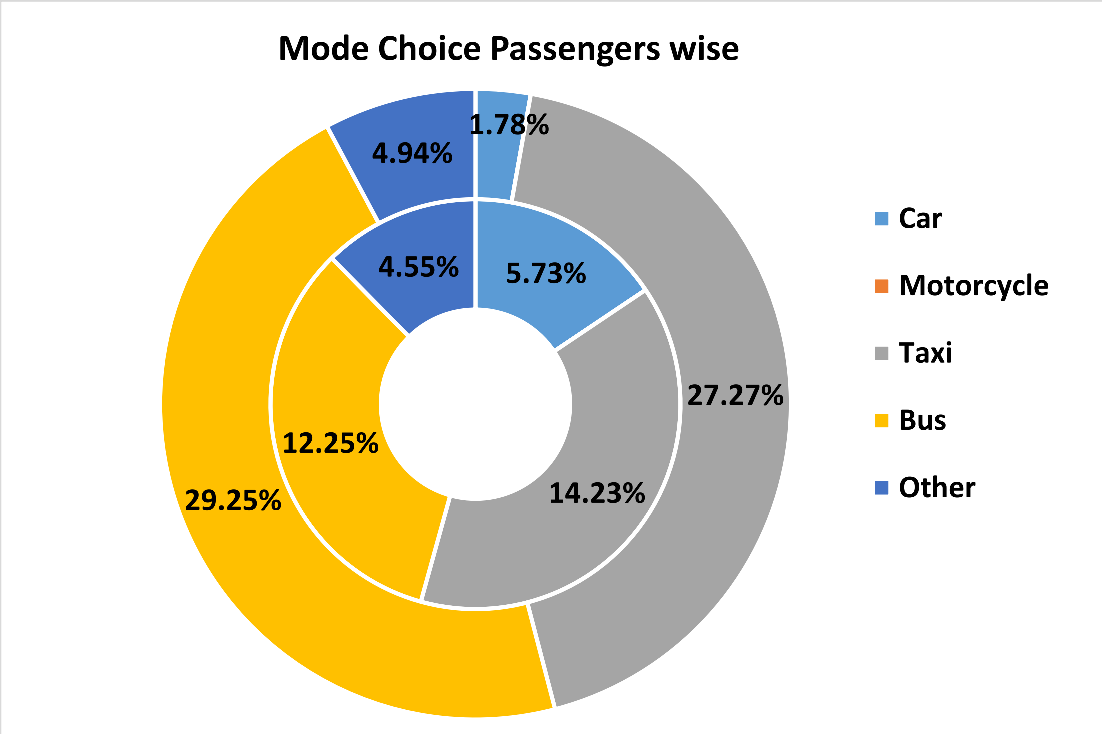

Figure 4.4 Representation of mode choice by passengers

The combined results of both drivers and passengers for different categories of modes are represented in Table 4.5. The proportions of gender choice of different modes are represented in Figure 4.5 with the inner doughnut representing female proportions while the outer shows male proportions of total sample.

Table 4.5 Representation of mode choice by gender

			Car	Motorcycle	Taxi	Bus	Other
Male	1336	**Outer doughnut**	294	420	276	296	50
Female	440	**Inner doughnut**	126	0	144	124	46

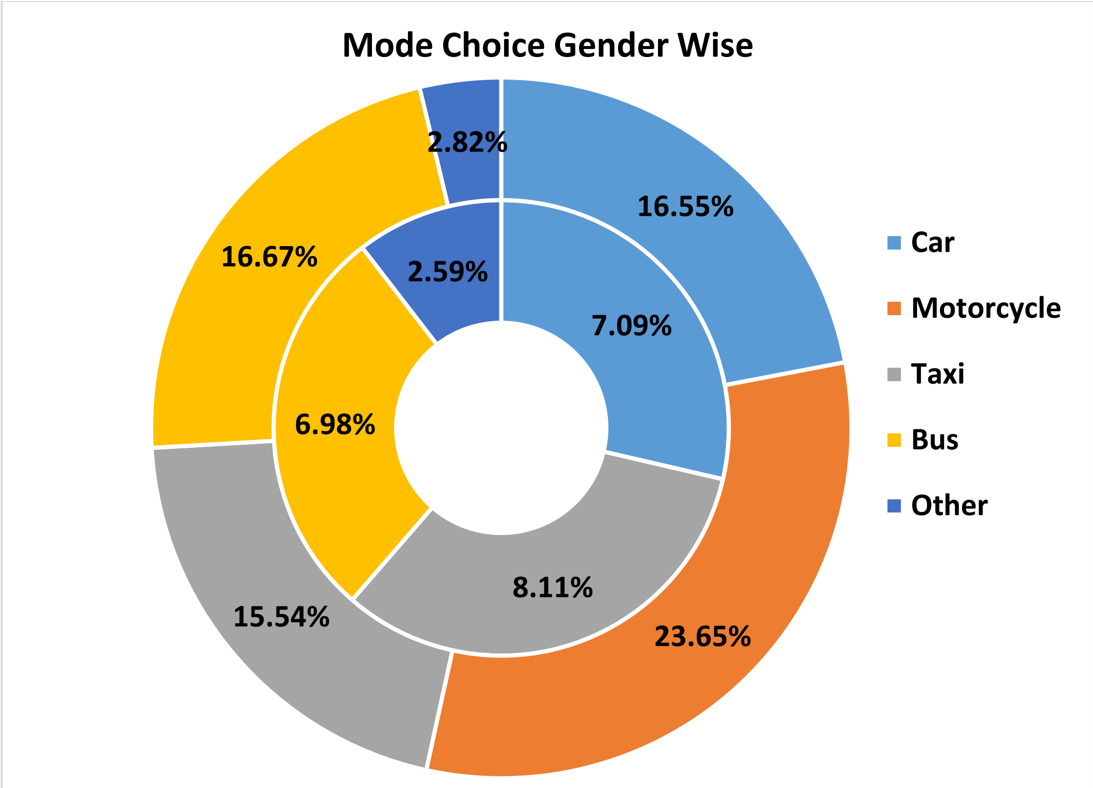

Figure 4.5 Representation of mode choice by gender

4.1.2 Age

The respondents are divide into three age groups which are: 14-30 years, 31-45 years, and 46+ years age groups. The different age groups are categorized as male and female with mode choices. The age group of 14-30 years consists of 1142 respondents is represented in Table 4.6 in which male and female respondents are 788 and 354 respectively, and current mode choices of both genders are shown. The proportions of commuters belonging to age group 14-30 years using different modes are represented in Figure 4.6 with inner doughnut representing female users while outer doughnut shows male users.

Table 4.6 Representation of mode choice by age group of 14-30 years

Age	Mode	Female	Male	Total
14-30	Car	112	162	274
	Motorcycle	0	232	232
	Taxi	110	176	286
	Bus	86	172	258
	Other	46	46	92
	Total	354	788	1142

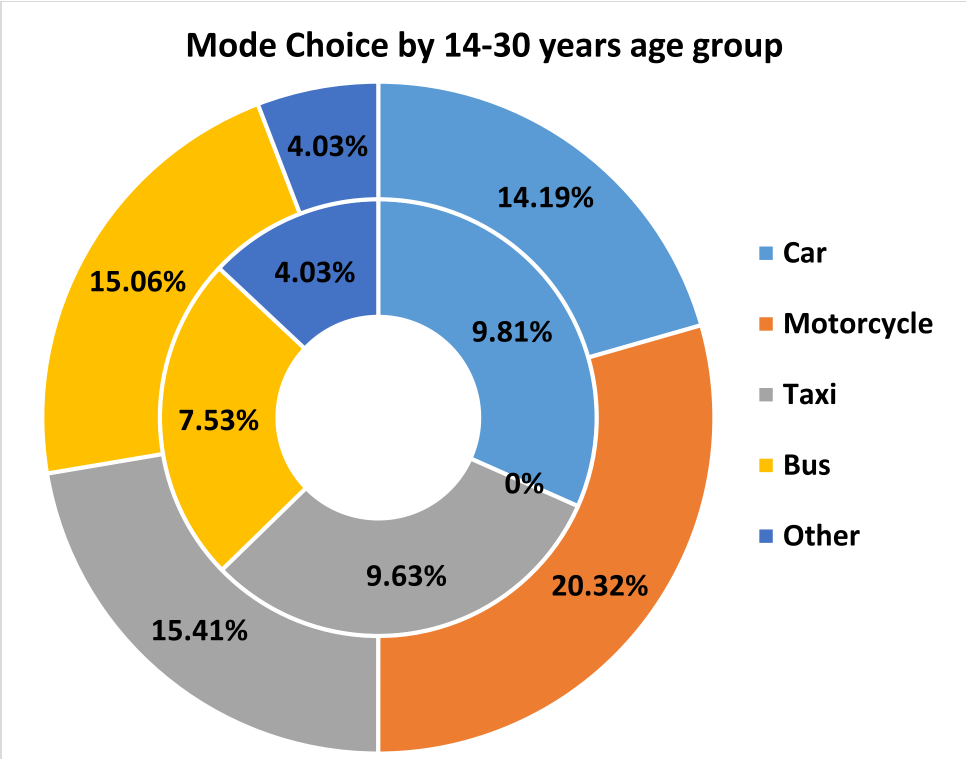

Figure 4.6 Representation of mode choice by 14-30 years age group

The respondents of age group 31-45 years consists 378 in which male and female are 304 and 74 respectively. The users data of both male and female with respect to different modes is shown in Table 4.7. The proportions of both genders with current mode choices is shown in Figure 4.7 with the inner doughnut representing female respondents while the outer represents male respondents.

Table 4.7 Representation of mode choice by age group of 31-45 years

Age	Mode	Female	Male	Total
31-45	Car	12	80	92
	Motorcycle	0	108	108
	Taxi	28	60	88
	Bus	34	52	86
	Other	0	4	4
	Total	74	304	378

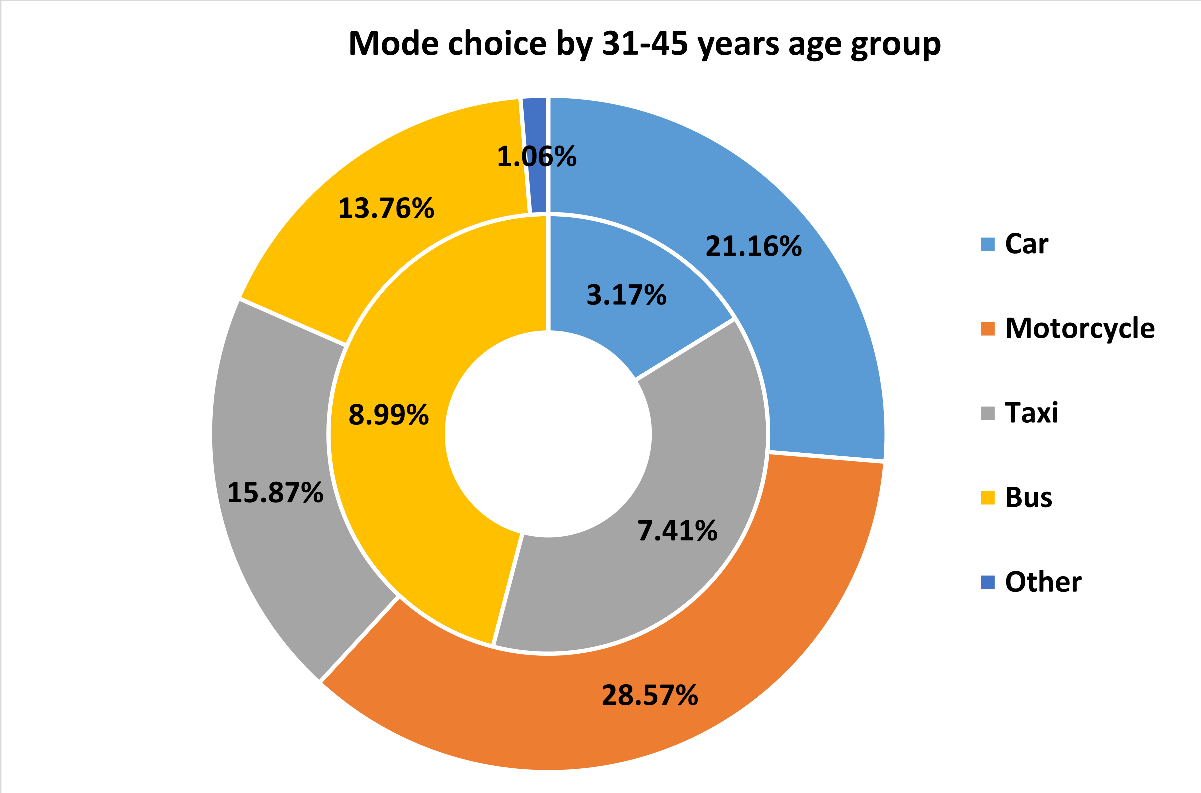

Figure 4.7 Representation of mode choice by 31-45 years age group

The age group of 46+ years consists of 256 respondents in which male and female respondents are 244 and 12 respectively as shown in Table 4.8. The proportion distribution for this age group is represented in Figure 4.8 with the inner doughnut showing female respondents while the outer represents male respondents.

Table 4.8 Representation of mode choice by age group of 46+ years

Age	**Mode**	**Female**	**Male**	**Total**
46+	Car	2	52	54
	Motorcycle	0	80	80
	Taxi	6	40	46
	Bus	4	72	76
	Other	0	0	0
	Total	12	244	256

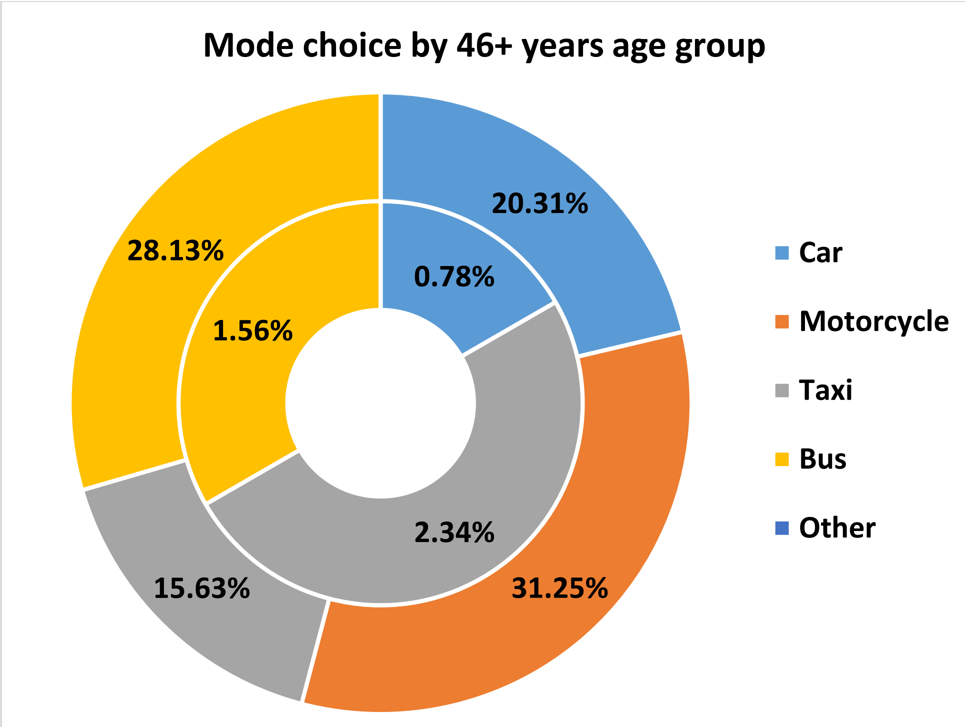

Figure 4.8 Representation of mode choice by 46+ years age group

The combined data for both male and female with different age groups using various modes is shown in Table 4.9. The age groups of 14-30, 31-45, and 46+ years consists of 1142, 378, and 256 respondents respectively. The proportions of different modes is represented in Figure 4.9 with inner, middle, and outer doughnuts showing age groups of 14-30, 31-45, and 46+ years.

Table 4.9 Representation of mode choice with different age groups

	Age	**Respondents**
Inner doughnut	14-30 years	1142
Middle doughnut	31-45 years	378
Outer doughnut	46+ years	256
Total		1776

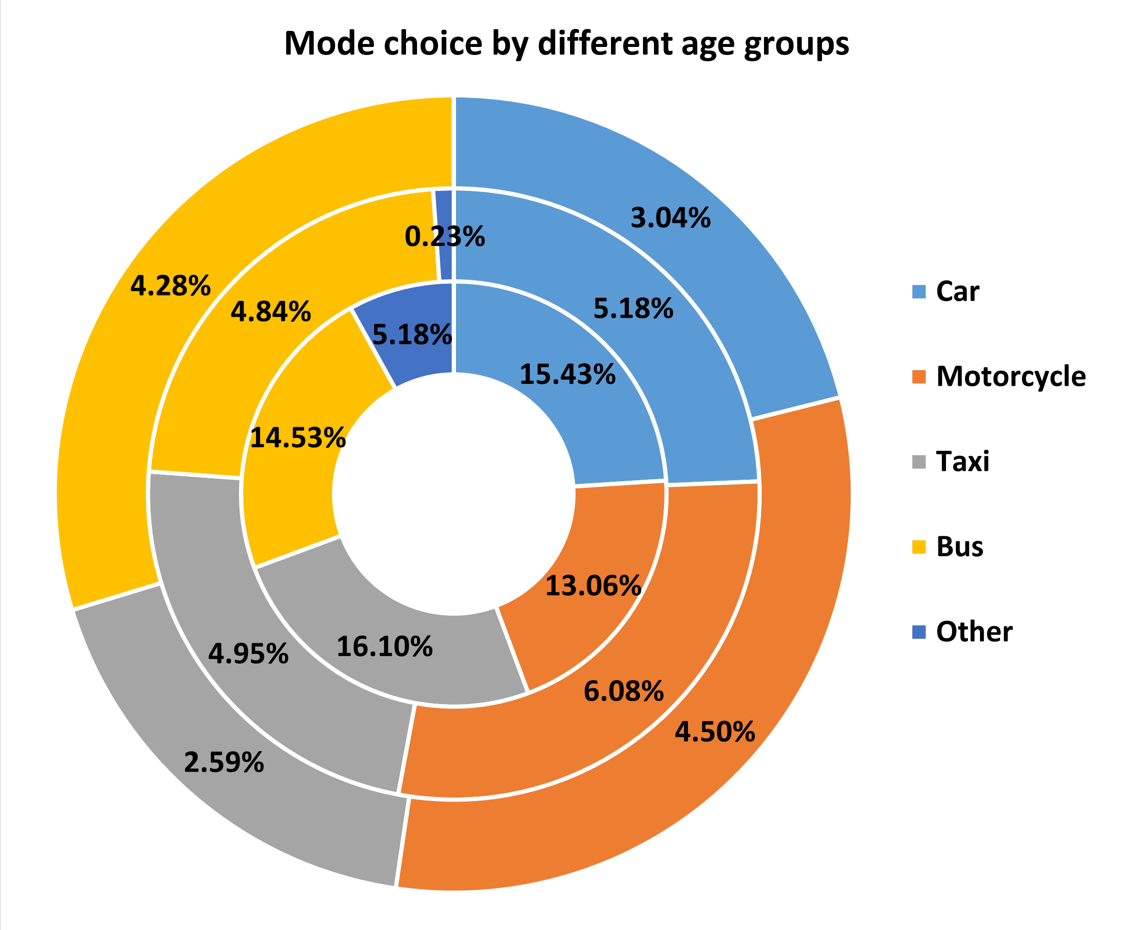

Figure 4.9 Representation of mode choice by different age groups

4.1.3 Trip Purpose

The data is also collected from respondent by trip purpose for various modes such as car, motorcycle, taxi, bus, and other modes. The trips for school/university, shopping, recreation, work, and other purposes consists of 772, 294, 42, 602, and 66 respondents as shown in Table 4.10. The proportions of users pertaining to different modes are represented with respect to trip purpose in Figure 4.10.

Table 4.10 Mode choice by trip purpose

Trip Purpose	Car	Motorcycle	Taxi	Bus	Other	Total
School/University	144	178	188	206	56	772
Shopping	78	46	88	68	14	294
Recreational	16	12	10	0	4	42
Work	154	178	120	136	14	602
Other	28	6	14	10	8	66

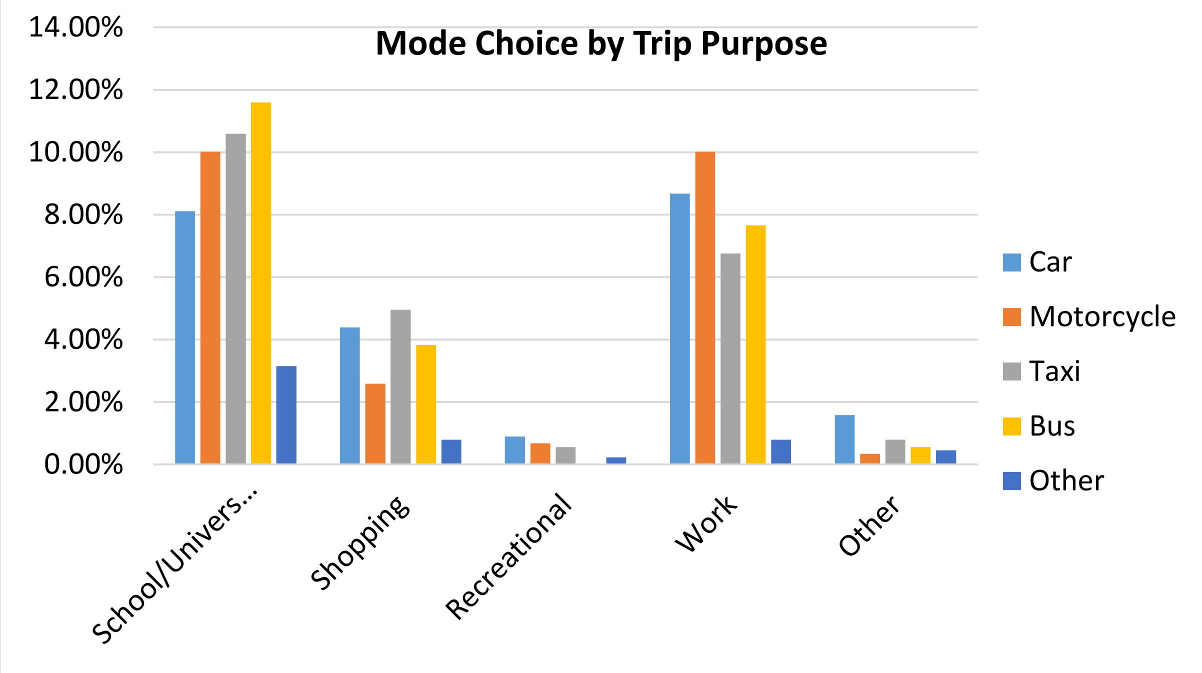

Figure 4.10 Representation of mode choice by trip purpose

4.1.4 Willingness of Shift

It can be observed from analysis that the commuters pertaining to bus mode have showed more willingness for BRT Peshawar as compared to other modes to be used as a mode of journey when it becomes operational. The analysis outcomes reveal that the users of bus, taxi, motorcycle, car, and other modes have showed willingness of 93.8, 59, 51.9, 33.8, and 79.17 percent towards BRT Peshawar respectively as shown in Table 4.11. The users of local bus have showed more willingness because after implementation of BRT service, the local bus service will be closed, so, the users will automatically shift, and second, BRT provides high quality service with the reduced travel time which is not provided by local buses in Peshawar. It is clearly represented in case of BRT Surat, India in which users of local buses have showed willingness of 78.575% towards BRT due to high quality service (Kumar & Electricwala, 2014). The lack of service of local buses is the reason for increase of private cars by 229% in a last decade in Peshawar city (Ali et al., 2012; Khan & Arshad, 2015; Ullah et al., 2019). The BRT on other hand provides high quality and reliable service which has the ability to attract commuters towards it. Therefore, BRT Peshawar has the potential to attract significant users towards it as clearly represented in Figure 4.11.

Table 4.11 Willingness of shift towards BRT Peshawar

Mode	Respondents	Shifts towards BRT Peshawar	Willingness of shift
Car	420	142	33.80%
Motorcycle	420	218	51.90%
Taxi	420	248	59%
Bus	420	394	93.80%
Other	96	76	79.17%

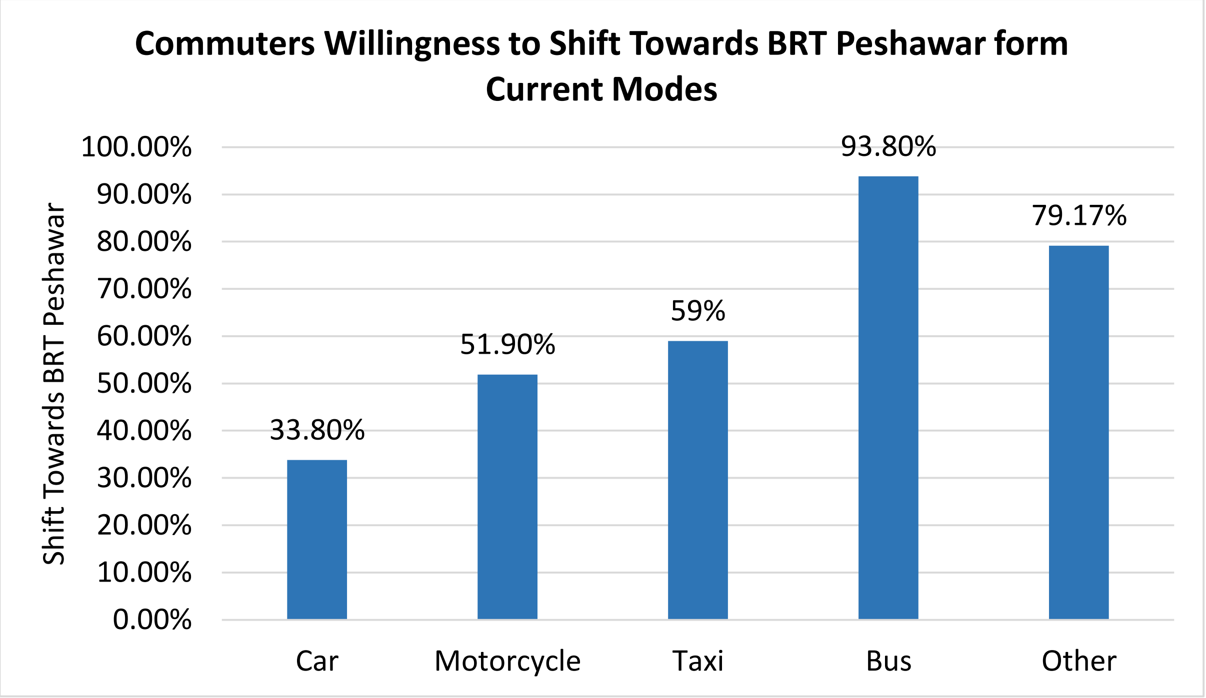

Figure 4.11 Commuter Willingness to shift towards BRT Peshawar

4.1.5 Travel Time

Travel time data is collected for BRT route and parallel road for six sections aforementioned in study area of methodology. The data for parallel road is collected in form of questionnaire and discussed in following sections for both BRT and parallel road sections.

4.1.5.1 For Parallel Road

The travel time data for parallel road is collected for three modes (car, taxi, and motorcycle) in six sections. The average travel time of modes is calculated for each section. The average data of travel time for the three modes is shown in Table 4.12.

Table 4.12 Travel time data for parallel road

Route	Distance (km)	Car Time (mins)	Taxi Time (mins)	Motorcycle Time (mins)
Tatara To Board	3.7	9.49	9.71	8.17
PDA To Karkhano	2.8	13.66	14.33	13.2
Tehkal To Saddar	3.7	22.94	21.51	20.86
Board To Peshawar Uni	1.5	10.57	12.69	9.83
Town To Tehkal	2.3	17.06	20.67	16.46
LRH To Haji Camp	2.9	22.37	27.78	22

The data of travel time for the sections is converted to travel time per kilometer to have a better representation and ease of comparison with each other. For this purpose, the travel time of the sections is divided by the length of corresponding sections to achieve travel time per kilometer as shown in Table 4.13.

Table 4.13 Travel time data per km for parallel road

Route	Car T/km (mins/km)	Taxi T/km (mins/km)	Motorcycle T/km (mins/km)
Tatara To Board	2.6	2.6	2.2
PDA To Karkhano	4.9	5.1	4.7
Tehkal To Saddar	6.2	5.8	5.6
Board To Peshawar Uni	7	8.5	6.6
Town To Tehkal	7.4	9	7.2
LRH To Haji Camp	7.7	9.6	7.6

4.1.5.2 For BRT Route

The travel time data for sections of BRT Peshawar was calculated by the average speed data collected from TransPeshawar department. The average speed of BRT Peshawar is 45km/hr and the average distance of each section is known. The travel time is found from known speed and distance, and is then converted to travel time per kilometer. According to TransPeshawar officials, BRT stay time at each station will be 20 seconds which comes out to be 0.33 minutes. As the average distance between stations is 850 meters so it stops once in one kilometer distance. So, the total travel time is calculated by adding the travel and stay time as shown in Table 4.14.

Table 4.14 Travel time per km data for BRT Peshawar

Route	Distance (km)	BRT Speed (kph)	BRT Time (mins)	BRT Time per km (mins/km)	BRT Stay time per km (mins/km)	BRT Total travel time (T) = BRT time + BRT stay time (mins/km)
Tatara To Board	3.7	45	4.93	1.33	0.33	1.66
PDA To Karkhano	2.8	45	3.73	1.33	0.33	1.66
Tehkal To Saddar	3.7	45	4.93	1.33	0.33	1.66
Board To Peshawar Uni	1.5	45	2	1.33	0.33	1.66
Town To Tehkal	2.3	45	3.07	1.33	0.33	1.66
LRH To Haji Camp	2.9	45	3.87	1.33	0.33	1.66

4.1.6 Speed Cycles

Speed cycles are the number of accelerations and decelerations involved during the travel from one place to other. The data of speed cycles is collected for BRT and parallel road for all six sections. The data of speed cycles for parallel road is collected in form of questionnaire survey. The data is discussed in following sections.

4.1.6.1 For Parallel Roads

The speed cycles data for three modes (car, taxi, and motorcycle) is collected in six sections. The data is collected from drivers of different modes as drivers know the correct data of speed cycles. The average speed cycle of modes is calculated for each section and is shown in Table 4.15.

Table 4.15 Speed cycles data for parallel road

Route	Distance (km)	Car Speed cycle	Taxi Speed cycles	Motorcycle Speed cycles
Tatara To Board	3.7	11.09	15.55	14.43
PDA To Karkhano	2.8	13.74	14.15	12.03
Tehkal To Saddar	3.7	19.71	20.6	20.34
Board To Peshawar Uni	1.5	12.43	10.05	11.91
Town To Tehkal	2.3	23.06	21.7	22.46
LRH To Haji Camp	2.9	31.6	30.8	29.86

The data of speed cycle for the sections is converted to speed cycles per kilometer to have a better representation and ease of comparison with each other. For this purpose, the speed cycles of the sections is divided by the length of corresponding sections to achieve speed cycles per kilometer as shown in Table 4.16.

Table 4.16 Speed cycles per km data for parallel road

Route	Distance (km)	Car Sped cycles/km	Taxi Speed cycles/km	Motorcycle Speed cycles/km
Tatara To Board	3.7	3	4.2	3.9
PDA To Karkhano	2.8	4.9	5.1	4.3
Tehkal To Saddar	3.7	5.3	5.6	5.5
Board To Peshawar Uni	1.5	8.3	6.7	7.9
Town To Tehkal	2.3	10	9.4	9.8
LRH To Haji Camp	2.9	10.9	10.6	10.3

4.1.6.2 For BRT Route

BRT Peshawar has average distance of 850 meters between stations so it stops once in a kilometer distance. Therefore, it has speed cycle of one per kilometer distance as shown in Table 4.17.

Table 4.17 Speed cycles per km data for BRT Peshawar

Route	Distance (km)	BRT Speed cycle/km
Tatara To Board	3.7	1
PDA To Karkhano	2.8	1
Tehkal To Saddar	3.7	1
Board To Peshawar Uni	1.5	1
Town To Tehkal	2.3	1
LRH To Haji Camp	2.9	1

4.1.7 Vehicle Operating Cost (VOC)

Vehicle operating cost for both BRT and parallel road modes (car, and taxi) is found through Hepburn model which takes into account four vehicle operating cost components (fuel, tyres, vehicle depreciation, and maintenance) as a function of two vehicle operating cost factors (average speed, and vehicle type). Hepburn model gives two equations for determining vehicle operating cost, one is for speed less than 50 mph while other is for speed greater than 50 mph. The equations for speed less than 50 mph and greater than 50 mph are given in Eq. (4.4), and Eq. (4.5) respectively (Sinha & Labi, 2011).

$$VOC = C + \frac{D}{S} \tag{4.4}$$

$$VOC = a_0 - a_1 + a_2S^2 \tag{4.5}$$

Where,
VOC = Vehicle operating cost in cents/veh.mile
S =Average speed in mph
C , D, a_0 , a_1, a_2 = Coefficients for different types of vehicles as given below.

Table 4.18 Parameters of Hepburn Model (Sinha & Labi, 2011)

Vehicle Type	C	D	a_0	a_1	a_2
Small Automobile	24.8	45.5	27.2	0.035	0.00021
Medium Automobile	28.5	25.3	33.5	0.058	0.00029
Large Automobile	29.8	163.4	38.1	0.093	0.00033

4.1.7.1 For Parallel Road

The vehicle operating cost of car and taxi modes requires the data of speed in the sections. The speed of the modes is found from the known distance and travel time of the sections for the car and taxi. The speed of the modes is converted into mph as the Hepburn models require speed data in this unit. The data of speed is shown in Table 4.19.

Table 4.19 Speed data for car and taxi modes

Route	Distance (km)	Car Speed (mph)	Taxi Speed (mph)
Tatara To Board	3.7	14.54	14.21
PDA To Karkhano	2.8	7.64	7.28
Tehkal To Saddar	3.7	6.01	6.41
Board To Peshawar Uni	1.5	5.29	4.41
Town To Tehkal	2.3	5.03	4.15
LRH To Haji Camp	2.9	4.83	3.89

The data of vehicle operating cost in rupees for motorcycle is collected from users of the mode for the section as already mentioned. The cost is converted to cents by knowing the dollar rate equal to Rs.162 at the time of analysis. The cost is divided by the length of the section to compute the vehicle operating cost in cents per veh.km as shown in Table 4.20

Table 4.20 Vehicle operating cost for motorcycle

Route	Distance (km)	Motorcycle Cost (Rs)	Motorcycle cost/km (Rs/km)	Motorcycle Cost cents/veh.km
Tatara To Board	3.7	23	6.22	3.84
PDA To Karkhano	2.8	29.26	10.45	6.45
Tehkal To Saddar	3.7	44.43	12.01	7.41
Board To Peshawar Uni	1.5	20.86	13.91	8.59
Town To Tehkal	2.3	35.29	15.34	9.47
LRH To Haji Camp	2.9	56.86	19.61	12.1

As the speed of car and taxi is less than 50 mph so Eq. (1) is used to calculate the vehicle operating cost for the two modes from known speed. The car and taxi comes in the category of small automobiles so the parameters of the respective automobiles are picked from Table 4.18. The vehicle operating cost is converted to cents/veh.km to have the similarity of units, and the final results for modes of parallel road is shown in Table 4.21.

Table 4.21 Results of vehicle operating cost for modes of parallel road

Route	Distance (km)	Car VOC cents/veh. mile	Car VOC cents/veh. km	Taxi VOC cents/veh. mile	Taxi VOC cents/veh. km	Motorcycle Cost cents/veh.km
Tatara To Board	3.7	37.1	17.36	28	17.4	3.84
PDA To Karkhano	2.8	41.05	19.12	31.05	19.3	6.45
Tehkal To Saddar	3.7	37.1	20.12	31.9	19.83	7.41
Board To Peshawar Uni	1.5	55.13	20.76	35.12	21.83	8.59
Town To Tehkal	2.3	44.58	21.04	35.76	22.22	9.47
LRH To Haji Camp	2.9	40.49	21.27	36.5	22.68	12.1

4.1.7.2 For BRT Route

The vehicle operating cost for BRT mode is calculated by having the data of speed collected from TransPeshawar department. The BRT mode comes in the category of large automobile so the parameters of the respective automobile are taken from Table 4.18. The average speed of BRT is 27.96 mph which is less than 50 mph so Eq. (1) is used for the calculation of vehicle operating cost. The VOC calculated is converted to cents per veh.km to have the similarity of units as shown in Table 4.22.

Table 4.22 Vehicle operating cost for BRT mode

Route	Distance (km)	BRT Speed (kph)	Brt speed (mph)	BRT VOC cents/veh.mile	BRT VOC cents/veh.km
Tatara To Board	3.7	45	27.96	35.64	22.15
PDA TO Karkhano	2.8	45	27.96	35.64	22.15
Tehkal To Saddar	3.7	45	27.96	35.64	22.15
Board To Peshawar Uni	1.5	45	27.96	35.64	22.15
Town To Tehkal	2.3	45	27.96	35.64	22.15
LRH To Haji Camp	2.9	45	27.96	35.64	22.15

4.1.8 Model Estimation Results

Binary logit models are constructed in order to determine the shifts of commuters pertaining to private modes towards BRT Peshawar. Three separate models are generated between private modes (including car, motorcycle, and taxi) and BRT Peshawar based on three service attributes of travel time (T), speed cycles (SC) and vehicle operating cost (VOC). The polynomial utility functions are developed for these modes which provides the basis for determining the shifts from each private mode towards BRT. The difference between service attributes of current mode and BRT will predict the modal shifts between two modes. The three models are discussed in detail in following sections.

4.1.8.1 Car vs. BRT Peshawar Binary Logit Model

The analysis results in the number of car users willing to shift towards BRT Peshawar in each section which gives the proportion of shifts towards BRT. The proportion of car users willing to shift towards BRT Peshawar is low for Tatara to Board Station while it is high for the LRH to Haji Camp Station as shown in Table 4.23.

Table 4.23 Car users willing to shift towards BRT Peshawar

Route	Car users willing to shift towards BRT	Respondents of car	Probability
Tatara To Board	10	70	0.1429
PDA To Karkhano	18	70	0.2571
Tehkal To Saddar	20	70	0.2857
Board To Peshawar Uni	28	70	0.4
Town To Tehkal	30	70	0.4286
LRH To Haji Camp	36	70	0.5143

The analysed data of service attributes (travel time, speed cycles, and VOC) for car is summarised in Table 4.24. The analysed data for service attributes of BRT mode is presented in Table 4.25.

Table 4.24 Car service attributes

Route	Car T/km (mins/km)	Car SC/km	Car VOC cents/veh.km
Tatara To Board	2.6	3	17.36
PDA TO Karkhano	4.9	4.9	19.12
Tehkal To Saddar	6.2	5.3	20.12
Board To Peshawar Uni	7	8.3	20.76
Town To Tehkal	7.4	10	21.04
LRH To Haji Camp	7.7	10.9	21.27

Table 4.25 BRT Peshawar service attributes

Route	BRT T/km (mins/km)	BRT SC/km	BRT VOC (cents/veh.km)
Tatara To Board	1.66	1	22.15
PDA TO Karkhano	1.66	1	22.15
Tehkal To Saddar	1.66	1	22.15
Board To Peshawar Uni	1.66	1	22.15
Town To Tehkal	1.66	1	22.15
LRH To Haji Camp	1.66	1	22.15

The service attributes of BRT mode are subtracted from service attributes of car which gives the change in service attributes (ΔT, ΔS, and ΔVOC) as shown in Table 4.26. The proportion of car users willing to shift are also presented in same table.

Table 4.26 Data for modelling of car vs. BRT Peshawar

Route	Probability of car shifts	ΔU	ΔT	ΔSC	ΔVOC
Tatara To Board	0.1429	1.7914	0.94	2	-4.79
PDA To Karkhano	0.2571	1.0611	3.24	3.9	-3.03
Tehkal To Saddar	0.2857	0.9164	4.54	4.3	-2.03
Board To Peshawar Uni	0.4	0.4055	5.34	7.3	-1.39
Town To Tehkal	0.4286	0.2876	5.74	9	-1.11
LRH To Haji Camp	0.5143	-0.0572	6.04	9.9	-0.88

The service attributes are subjected to correlate among each other to determine the coefficients of correlation as shown in Table 4.27. The values of coefficient of correlation are greater than 0.9 which reveals that the service attributes are highly correlated.

Table 4.27 Coefficient of correlation among independent variables of car vs. BRT model

	ΔT	ΔSC	ΔVOC
ΔT	1		
ΔSC	0.92	1	
ΔVOC	1	0.91	1

Regression analysis is performed between the change in utility and the change in service attribute of the car and BRT mode. Model estimation results for car and BRT model are generated and are presented in Table 4.28. The results reveals that the coefficients of all three service attributes (ΔT, ΔSC and ΔVOC) for the model are showing negative signs which indicates the direct relationship between service attributes and modal shifts of BRT Peshawar. The increase in values of these attributes will result in decrease in value of change in utility (ΔU) which in turn will increase the modal shifts.

The outcomes of model between car and BRT depicts that the vehicle operating cost is the main factor as compared to other service attributes (speed cycles and travel time) while the second most important is speed cycle that will be contributing the shifts of commuters from car to BRT Peshawar as shown in Table 4.28. The results show that increase in the vehicle operating cost and speed cycles of car will compel more commuters to make a journey by BRT Peshawar.

Table 4.28 Model estimation results for car vs. BRT Peshawar

	Coefficients	t Stat	P-value
Intercept	0.9104	2.76	0.02
ΔT	-0.0061	-1.98	0.05
ΔSC	-0.1054	-2.3917	0.03
ΔVOC	-0.222	-3.47	0.01
Multiple R	0.9929		
R Square	0.9859		
Adjusted R Square	0.9648		
Standard Error	0.1242		
Observations	420		
R Square (Validated)	0.9828		

Model is validated by comparing the estimation results with the known results from survey showing R^2 of 0.9828 which show that model is well validated. Model statistics predicts that the model is well calibrated and infers correctly about the modal shifts. The statistics for binary logit model including standard deviation, p value, R^2, and t-statistic are calculated and presented in Table 4.28. It shows that all constants and attributes have t-statistic values greater than 1.96 and standard deviation which contributes to the significance of model having no significant difference from average. The p-value is less than 0.05 which describes the correctness of the models (Rumsey, 2015). The estimate of coefficients of determination (R^2) for the model is 0.98 which reveals the goodness of fit in the model that correctly predicts the results.

4.1.8.2 Taxi vs. BRT Peshawar Binary Logit Model

The analysis results in the number of taxi users willing to shift towards BRT Peshawar in each section which gives the proportion of shifts of taxi users towards BRT. The proportion of taxi users willing to shift towards BRT Peshawar is low for Tatara to Board Station while it is high for the LRH to Haji Camp Station as shown in Table 4.29.

Table 4.29 Taxi users willing to shift towards BRT Peshawar

Route	Taxi users willing to shift towards BRT	Respondents of Taxi	Probability
Tatara To Board	28	70	0.4
PDA TO Karkhano	34	70	0.4857
Tehkal To Saddar	38	70	0.5429
Board To Peshawar Uni	46	70	0.6571
Town To Tehkal	48	70	0.6857
LRH To Haji Camp	54	70	0.7714

The analysed data of service attributes (travel time, speed cycles, and VOC) for car is summarised in Table 4.30 while the analysed data for service attributes of BRT mode is presented in Table 4.25.

Table 4.30 Taxi service attributes

Route	Taxi T/km (mins/km)	Taxi SC/km	Taxi VOC (cents/veh.km)
Tatara To Board	2.6	4.2	17.4
PDA TO Karkhano	5.1	5.1	19.3
Tehkal To Saddar	5.8	5.6	19.83
Board To Peshawar Uni	8.5	6.7	21.83
Town To Tehkal	9	9.4	22.22
LRH To Haji Camp	9.6	10.6	22.68

The service attributes of BRT mode are subtracted from service attributes of taxi mode which gives the change in service attributes (ΔT, ΔS, and ΔVOC) as shown in Table 4.31. The proportion of taxi users willing to shift are also presented in same table.

Table 4.31 Data for modelling of taxi vs. BRT Peshawar

Route	Probability of taxi shift	ΔU	ΔT	ΔSC	ΔVOC
Tatara To Board	0.4	0.4055	0.94	3.2	-4.75
PDA To Karkhano	0.4857	0.0572	3.44	4.1	-2.85
Tehkal To Saddar	0.5429	-0.172	4.14	4.6	-2.32
Board To Peshawar Uni	0.6571	-0.6504	6.84	5.7	-0.32
Town To Tehkal	0.6857	-0.7801	7.34	8.4	0.07
LRH To Haji Camp	0.7714	-1.2162	7.94	9.6	0.53

The service attributes are subjected to correlate among each other to determine the coefficients of correlation as shown in Table 4.32. The values of coefficient of correlation are greater than 0.9 which reveals that the service attributes are highly correlated.

Table 4.32 Coefficient of correlation among independent variables of taxi vs. BRT model

	ΔT	**ΔSC**	**ΔVOC**
ΔT	1		
ΔSC	0.9	1	
ΔVOC	1	0.9	1

Regression analysis is performed between change in utility and service attributes of taxi and BRT mode which gives model estimation results, and are presented in Table 4.23. The results reveals that the coefficients of all three service attributes (ΔT, ΔSC and ΔVOC) for the model are showing negative signs which indicates the direct relationship between service attributes and modal shifts of BRT Peshawar. The increase in values of these attributes will result in decrease in value of change in utility (ΔU) which in turn will increase the modal shifts.

The model results for the taxi and BRT Peshawar indicates importance of travel time that is most influencing service attribute in this model which effects the shifts at large as shown in Table 4.33. Second service attribute which effects the modal share is speed cycle. These outcomes explain the increase of both service attributes will result in large modal shifts of commuters pertaining to private mode (taxi) to BRT Peshawar.

Table 4.33 Model estimation results for taxi vs. BRT Peshawar

	Coefficient	**t Stat**	**P-value**
Intercept	0.7932	3.305	0.011
ΔT	-0.1299	-2.7	0.022
ΔSC	-0.0908	-2.14	0.04
ΔVOC	-0.0101	-2.36	0.034
Multiple R	0.9896		
R Square	0.9792		
Adjusted R Square	0.948		
Standard Error	0.1361		
Observations	420		
R Square (Validated)	0.985		

Model is validated by comparing the estimation results with the known results from survey showing R^2 of 0.985 which show that model is well validated. Model statistics predicts that the model is well calibrated and infers correctly about the modal shifts. The statistics for binary logit model including standard deviation, p value, R^2, and t-statistic are calculated and presented in Table 4.33. It shows that all constants and attributes have values of t-statistic greater than 1.96 and lower values of standard deviation which contributes to the significance of model having no significant difference from average. The p-value is less than 0.05 which describes the correctness of the models (Rumsey, 2015). The estimate of coefficients of determination (R^2) for the model is 0.98 which reveals the goodness of fit in the model that correctly predicts the results.

4.1.8.3 Motorcycle vs. BRT Peshawar Binary Logit Model

The motorcycle users willing to shift towards BRT Peshawar are found out as a result of analysis in each section which gives the proportion of shifts of motorcycle users towards BRT. The proportion of motorcycle users willing to shift towards BRT Peshawar is low for Tatara to Board Station while it is high for the LRH to Haji Camp Station as shown in Table 4.34.

Table 4.34 Motorcycle users willing to shift towards BRT Peshawar

Route	Motorcycle users willing to shift towards BRT	Respondents of Motorcycle	Probability
Tatara To Board	22	70	0.3143
PDA TO Karkhano	26	70	0.3714
Tehkal To Saddar	36	70	0.5143
Board To Peshawar Uni	42	70	0.6
Town To Tehkal	44	70	0.6286
LRH To Haji Camp	48	70	0.6857

The analysed data of service attributes (travel time, speed cycles, and VOC) for motorcycle is summarised in Table 4.35 while the analysed data for service attributes of BRT mode is presented in Table 4.25.

Table 4.35 Motorcycle service attributes

Route	Motorcycle T/km	Motorcycle SC/km	Motorcycle Cost (cents/veh.km)
Tatara To Board	2.2	3.9	3.84
PDA TO Karkhano	4.7	4.3	6.45
Tehkal To Saddar	5.6	5.5	7.41
Board To Peshawar Uni	6.6	7.9	8.59
Town To Tehkal	7.2	9.8	9.47
LRH To Haji Camp	7.6	10.3	12.1

The service attributes of BRT mode are subtracted from service attributes of motorcycle mode which gives the change in service attributes (ΔT, ΔS, and ΔVOC) as shown in Table 4.36. The proportion of motorcycle users willing to shift are also presented in same table.

Table 4.36 Data for modelling of motorcycle vs. BRT Peshawar

Route	Probability	ΔU	ΔT	ΔSC	ΔVOC
Tatara To Board	0.3143	0.7801	0.54	2.9	-18.31
PDA To Karkhano	0.3714	0.5262	3.04	3.3	-15.7
Tehkal To Saddar	0.5143	-0.0572	3.94	4.5	-14.74
Board To Peshawar Uni	0.6	-0.4055	4.94	6.9	-13.56
Town To Tehkal	0.6286	-0.5262	5.54	8.8	-12.68
LRH To Haji Camp	0.6857	-0.7801	5.94	9.3	-10.05

The service attributes are subjected to correlate among each other to determine the coefficients of correlation as shown in Table 4.37. The values of coefficient of correlation are greater than 0.9 which reveals that the service attributes are highly correlated.

Table 4.37 Coefficient of correlation among independent variables of motorcycle vs. BRT model

	ΔT	ΔSC	ΔVOC
ΔT	1		
ΔSC	0.9	1	
ΔVOC	0.95	0.93	1

Regression analysis is performed which gives model estimation results for motorcycle and BRT mode, and are presented in Table 4.38. The results reveals that the coefficients of all three service attributes (ΔT, ΔSC and ΔVOC) for the model are showing negative signs which indicates the direct relationship between service attributes and modal shifts of BRT Peshawar. The increase in values of these attributes will result in decrease in value of change in utility (ΔU) which in turn will increase the modal shifts.

The model constructed for motorcycle and BRT Peshawar reveals that travel time effects the inter-shifts between motorcycle and BRT while the second influencing service attribute is speed cycles as presented in Table 4.38. It shows that either increase or decrease of both aforementioned service attributes will affect the shifts of commuters pertaining to motorcycle mode

Table 4.38 Model estimation results for motorcycle vs. BRT Peshawar

	Coefficient	t Stat	P-value
Intercept	0.8659	2.67	0.02
ΔT	-0.1491	-2.13	0.04
ΔSC	-0.0994	-1.98	0.05
ΔVOC	-0.0172	-2.34	0.03
Multiple R	0.9826		
R Square	0.9655		
Adjusted R Square	0.9138		
Standard Error	0.1811		
Observations	420		
R Square (Validated)	0.9687		

Model is validated by comparing the estimation results with the known results from survey showing R^2 of 0.9687 which show that model is well validated. Model statistics predicts that the model is well calibrated and infers correctly about the modal shifts. The statistics for binary logit model including standard deviation, p value, R^2, and t-statistic are calculated and presented in Table 4.38. It shows that all constants and attributes have values of t-statistic greater than 1.96 and lower value of standard deviation which contributes to the significance of model having no significant difference from average. The p-value is less than 0.05 which describes the correctness of the models (Rumsey, 2015). The estimate of coefficients of determination (R^2) for the model is 0.98 which reveals the goodness of fit in the model that correctly predicts the results.

The summarized results of models estimations are presented in Table 4.39 which gives the polynomial utility function for three modes. These change in utility functions determine the modal shifts of the three modes towards BRT Peshawar on basis of three service attributes.

Table 4.39 Summarised results of model estimations

Mode	Utility Function
Car vs. BRT	$\Delta U = 0.9104 - 0.0061\Delta T - 0.1054\Delta SC - 0.222\Delta VOC$
Motorcycle vs. BRT	$\Delta U = 0.8659 - 0.1491\Delta T - 0.0994\Delta SC - 0.0172\Delta VOC$
Taxi vs. BRT	$\Delta U = 0.7932 - 0.1299\Delta T - 0.0908\Delta SC - 0.0101\Delta VOC$

4.2 Evaluation of BRT Peshawar by Comparison with BRT Standards 2016

The BRT Standard is a tool which evaluates BRT with international practices followed around the world. It acts as a planning and scoring tool which assists in defining a framework for planners, decision makers, and designers to implement a BRT that ensures high quality and reliable services. The evaluation tool is based on some essential elements that defines the quality and performance of BRT by scoring the elements. It results in the rankings of BRT as gold, silver, bronze, and basic BRT. The first three ranking shows the excellence of projects from gold as excellent to bronze as a good category while basic BRT lies in the category which just justify the corridor as a BRT by achieving minimum criteria.

This research has evaluated the BRT Peshawar by comparison with the "BRT Standards 2016". The elements on behalf of which the evaluation is carried out are: BRT basics, service planning, infrastructure, stations, communications, and access and integration which are further sub-categorized. The data was collected from field visits and TransPeshawar department which assisted to carry out evaluation.

4.2.1 BRT Basics

The BRT basics consists of elements that are essential minimum criteria to consider the corridor as a BRT. It provides the basics without which the project will not be considered as BRT and is the condition for further achieving bronze, silver, and gold categories. The elements include dedicated right of way, busway alignment, off-board fare collection, intersection treatment, platform-level boarding. The BRT corridor must achieve minimum score of 20 for all five elements, and must achieve a score of 4 on both dedicated right of way and busway alignment. BRT Peshawar has achieved 38/38 score in BRT basics while 8/8 for both dedicated right of way and busway alignment. The elements of BRT basics are discussed as follows:

4.2.1.1 Dedicated Right-of-Way

A dedicated right-of-way ensures the high speed of bus which is unaffected by congestion. There are many ways to separate a corridor from a mixed traffic but physical separation like fencing, prevent the corridor to be used by vehicles except bus. A corridor must be of at least 3km to be defined as BRT and BRT Peshawar is 26km long corridor that is physically separated by fencing with dedicated lanes. The score for physically separated, color-differentiated dedicated lane without physical separation, dedicated lanes segregated by painted line, and without dedicated lane is 8, 6,4, and 0 respectively (ITDP, 2016). BRT Peshawar achieved a score of 8/8 in this regard.

4.2.1.2 Busway Alignment

The best location for busway alignment is where there are minimum conflicts with other vehicles. The busway in the centre of the roadway faces reduced conflicts as compared to busway on the curb side due to minimizing conflicts of turning and access to curbside. BRT Peshawar runs in the middle of two way Jamrud Road with median aligned two-way busway. The scoring criteria is shown in Table 4.40. BRT Peshawar achieved a score of 8/8 in this element.

Table 4.40 Scoring criteria for busway alignment (ITDP, 2016)

Corridor Configurations	POINTS	WEIGHTED BY
TIER 1 CONFIGURATIONS		% of corridor with type of dedicated right-of-way
Two-way median-aligned busway in the central verge of a two-way road	8	
Bus-only corridor where there is a fully exclusive right-of-way and no parallel mixed traffic, such as a transit mall (e.g., Bogotá, Colombia; Curitiba, Brazil; and Quito, Ecuador) or a converted rail corridor (e.g., Cape Town, South Africa, and Los Angeles)	8	
Busway that runs adjacent to an edge condition like a waterfront or park where there are few intersections to cause conflicts	8	
Busway that runs two-way on the side of a one-way street	6	
TIER 2 CONFIGURATIONS		
Busway that is split into two one-way pairs on separate streets, with each bus lane centrally aligned in the roadway	5	
Busway aligned to the outer curb of the central roadway on a street with a central roadway and parallel service road	4	
Busway aligned to the inner curb of the service road on a street with a central roadway and parallel service road. Busway must be physically separated from other traffic on the service road to receive points	4	
Busway that is split into two one-way pairs on separate streets, with each bus lane aligned to the curb	3	
TIER 3 CONFIGURATIONS		
Virtual busway that operates bidirectionally in a single median lane that alternates direction by block.	1	
NON-SCORING CONFIGURATIONS		
Curb-aligned busway on a two-way road	0	

4.2.1.3 Off-board Fare Collection

Off-board fare collection helps to reduce the travel time of the trip, and also improve the experience of passengers. It can be done by two approaches: Barrier-controlled, and proof-of-payment. In first approach, passengers enter through turnstile, gate or checkpoint where they have to show the proof of payment or pay by smart card, while in second approach passenger buy tickets and are checked by inspectors on boarding to vehicle. The scoring criteria is shown in Table 4.41. The stations which are barrier-controlled are awarded maximum score of 8. BRT Peshawar have all stations barrier-controlled in which turnstile will be installed that will speed-up the journey of users. So, it is awarded 8/8 score in this element.

Table 4.41 Scoring criteria for off-board fare collection (ITDP, 2016)

Off-Board Fare Collection (During All Operating Hours)	POINTS	WEIGHTED BY
Barrier-controlled	8	% stations on corridor
Proof-of-payment	7	% routes using corridor bus infrastructure
Onboard fare validation—all doors	4	% routes using corridor bus infrastructure

4.2.1.4 Intersection treatment

Intersection is the important element that significantly effects the travel time, speed, and delays. A well-treated intersection helps to reduce travel time and delays, and increase the speed of vehicle. The signal priority intersection is useful on low frequency BRT corridors which is activated when BRT vehicle approaches. The prohibited turns across the BRT lane is more effective in reducing the delays, and travel time. BRT Peshawar has prohibited turns across the bus lanes by having fencing throughout the corridor. The scoring criteria is shown in Table 4.42. It is awarded 7/7 score in intersection treatment.

Table 4.42 Scoring criteria for intersection treatment (ITDP, 2016)

Intersection Treatments	POINTS	WEIGHTED BY
Turns prohibited across the busway	7	% of turns across busway prohibited
Signal priority at intersections	2	% of intersections on corridor

4.2.1.5 Platform-Level Boarding

The platform-level boarding is an important element in sustainable urban transportation that provides safe and comfortable boarding to the passengers. It reduces the delays caused due to disabled persons in alighting and boarding at stations which increase the efficiency of the system. The vertical gap between the station platform and the bus floor should be either 4 centimeters or less to account for comfortable and safe boarding of disabled passengers. The scoring criteria is given in Table 4.43. All busses of BRT Peshawar have floor level with the platform of stations having less than 4 centimeters of vertical gaps. The maximum score for the aforementioned element is 7 and BRT Peshawar achieved a 7/7 score in this element.

Table 4.43 Scoring criteria for Platform-level Boarding (ITDP, 2016)

Platform-Level Boarding	POINTS	WEIGHTED BY
Buses are platform level, having 4 centimeters (1 ½ inches) or less of vertical gap	7	% of buses operating on corridor
Stations in corridor have measures for reducing the horizontal gap	6	% of stations on corridor

4.2.2 Service Planning

Service planning helps to ensure that the system has the capacity to overcomes the current needs as well as future demand of transportation to have a sustainable urban transportation. It has various elements which are: multiple routes, express, limited-stop and local services, control center, demand profile, multi-corridor network, hours of operation, demand profile, and location in top ten corridors. BRT Peshawar scored 16/19 in service planning criteria which is representation of good planning. The various elements are discussed as follows:

4.2.2.1 Multiple Routes

Multiple routes operating in a corridor that goes to various destinations helps to reduce the door to door travel time by decreasing the transfer time. The BRT Standards assign a score of 4, and 0 to multiple routes, and no multiple routes respectively. The scoring criteria is shown in Table 4.44. BRT Peshawar has a single corridor that runs from

Chamkani to Karkhano Market including five feeder routes that will help to reduce the travel time of passengers. Therefore, it has achieved a score of 4/4 in this element.

Table 4.44 Scoring criteria for Multiple routes (ITDP, 2016)

Multiple Routes	POINTS
Two or more routes exist on the corridor, servicing at least two stations	4
No multiple routes	0

4.2.2.2 Express, Limited-Stop, and Local Services

BRT corridors operating with express and limited-stop services reduce the travel time and increase the speed of journey. Express service carry passengers from one end to the other end of the corridor or to the city centre and stops at few stations, while limited-stop services stops at high demand stations and skips stations of lower demand. The local service provides pick and drop at each and every station in corridor. The scoring criteria for the multiple services is shown in Table 4.45. BRT Peshawar have all express, limited-stop, and local services. Hence, it achieved a score of 3/3 for the mentioned criteria.

Table 4.45 Scoring criteria for various multiple services (ITDP, 2016)

Service Types	POINTS
Local services and multiple types of limited-stop and/or express services	3
At least one local and one limited-stop or express service option	2
No limited-stop or express services	0

4.2.2.3 Control Center

Control center are essential for monitoring operations of BRT as well as to respond problems directly to the operators. It uses Global Positioning System (GPS) and automatic vehicle location (AVL) to monitor the location, incidents, spacing, maintenance status, and records passenger alighting and boarding of BRT buses in real time to respond control center for further action. BRT standards have established scoring criteria for various control centers from full service to limited functional control centers. A full service control centers have automated dispatch, active bus control, and AVL system to increase quality of BRT service as well as reduce travel time of passengers by proper monitoring. The scoring criteria is shown in Table 4.46. Peshawar BRT have a full service control center including all services at Chamkani that will monitor the operations of BRT buses. Subsequently, it scored 3/3 in this criteria.

Table 4.46 Scoring criteria for control center (ITDP, 2016)

Control Center	POINTS
Full-service control center with all three services	3
Control center with two of the three services	2
Control center with one of the three services	1
No control center or center with limited functionality	0

4.2.2.4 Located in Top Ten Corridors

A significant proportion of commuters can be attracted by BRT system if it lies in the corridor that is a better choice for BRT and, can attract users. The maximum score of 2 is awarded if BRT corridor lies in top demand corridor. The scoring criteria is shown in Table 4.47. BRT Peshawar is located in top ten corridors, and is a better choice that will attract significant commuters. Therefore, it scored 2/2 in this element.

Table 4.47 Scoring criteria for location of corridor (ITDP, 2016)

Corridor Location	POINTS
Corridor is one of top ten demand corridors	2
Corridor is not one of top ten demand corridors	0

4.2.2.5 Demand Profile

The efficiency of BRT system can be improved if the dedicated corridor having good alignment is constructed in the highest demand segment of the route. It will ensure to improve the quality as well as reduce the travel time of passengers. The scoring criteria for this element is shown in Table 4.48. BRT Peshawar is located in the highest demand area of Peshawar running in the middle of two-way road with two-way busway. So, it scored 3/3 in the demand profile criteria.

Table 4.48 Scoring criteria for demand profile (ITDP, 2016)

Demand Profile	POINTS
Corridor includes highest demand segment, which has a Tier 1 Trunk Corridor configuration	3
Corridor includes highest demand segment, which has a Tier 2 Trunk Corridor configuration	2
Corridor includes highest demand segment, which has a Tier 3 Trunk Corridor configuration	1
Corridor does not include highest demand segment	0

4.2.2.6 Hours of Operation

A good BRT service should operate throughout the whole day until midnight and seven days a week to seek the attention of commuters otherwise they will prefer other modes for trip making. The scoring criteria is shown in Table 4.49. BRT Peshawar will operate between 6:00AM to 10:00PM in the whole week, and will not provide late night services. Therefore, it scored 1/2 in this criteria.

Table 4.49 Scoring criteria for operational hours (ITDP, 2016)

Operating Hours	POINTS
Both late-night and weekend service	2
Late-night service, no weekends or weekend service, no late nights	1
No late-night or weekend service	0

4.2.2.7 Multi-Corridor Network

Multi-corridor network is more viable in BRT system as it provides travel options to commuters for movement in the urban areas. It results in improved experience of passengers and ultimately increase the ridership of the service. The scoring criteria is shown in Table 4.50. BRT Peshawar has a single corridor and scored 0/2 as there are no planned networks that will connect the existing corridor.

Table 4.50 Scoring criteria for multi-corridor networks (ITDP, 2016)

Multi-Corridor Network	POINTS
BRT corridor connects to an existing BRT corridor or to the next one planned in the network	2
BRT corridor connects to a future planned corridor in the BRT network	1
No connected BRT network planned or built	0

4.2.3 Infrastructure

Infrastructure is the fundamental element in any urban transportation scheme that provides a ride quality and user satisfaction of the journey. BRT Standards has introduced various components for scoring criteria of infrastructure which are: passing lanes, reduction in bus emission, stations set back from intersections, center stations, and quality of pavement which are further explained below. BRT Peshawar scored 10/13 in criteria of infrastructure which depicts the good and high quality infrastructure.

4.2.3.1 Passing Lanes at Stations

Passing lanes play an important role in safe maneuvering and travel time saving of passengers at stations. The local and express services need passing lanes to avoid bunching of buses, and increase capacity at stations for maintaining speed. In some cases, overtaking in oncoming lane is permitted given safe circumstances when there are no passing lanes. The maximum score for the passing lanes criteria is 3. The scoring criteria is shown in given Table 4.51. BRT Peshawar have no passing lanes, and therefore scored 0/3 in the given criteria.

Table 4.51 Scoring criteria for passing lanes (ITDP, 2016)

Passing Lanes	POINTS
Dedicated passing lanes	3
Buses overtake in oncoming dedicated bus lanes given safe conditions	2
Passing in mixed traffic given safe conditions	1
No passing lanes	0

4.2.3.2 Minimizing Bus Emissions

The urban pollution has increased to the large extent now-a-days due to emissions of vehicles plying on roads that effects the surrounding environment. The main concerned pollutants released by buses are nitrogen oxides ($N0_X$), and particulate matter (PM). These pollutants need to be minimized to have a sustainable urban development by improving health of both passengers and surrounding population. It will increase the quality of BRT service. The scoring criteria is shown in Table 4.52. BRT Peshawar scored 3/3 as it has diesel hybrid buses which are in compliance with Euro VI emission standards.

Table 4.52 Scoring criteria for emission control (ITDP, 2016)

Emissions Standards	POINTS
Euro VI or US 2010	3
Euro V with PM traps, Euro IV with PM traps, or U.S. 2007	2
Euro V, Euro IV, Euro III CNG, or Euro III using verified PM trap retrofit	1
Below the above standards	0

4.2.3.3 Stations Set Back from Intersections

BRT Standards has specified a least distance of 26 meters for stations from intersections to avoid but ideally a minimum distance of 40 meters should be provided to avoid congestion and delays at intersections. The traffic signal will increase the queues and delays of buses if stations are located just before intersection, and will block the way of other buses to pull in. The stations should be separated from intersections to mitigate the issues of congestion and delays at stations. The scoring criteria is shown in Table 4.53. BRT Peshawar has a dedicated corridor which does not encounter intersections, and thus achieved 3/3 score in this element.

Table 4.53 Scoring criteria for stations location from intersections (ITDP, 2016)

Station Location	POINTS
75% of stations on corridor are set back at least 40 meters (130 feet) from intersections or meet at least one of the above exemptions	3
75% of stations on corridor are set back 26 meters (85 feet) from intersections or meet above exemptions	2
25% of stations on corridor are set back 26 meters (85 feet) from intersections or meet above exemptions	1
< 25% of stations on corridor are set back 26 meters (85 feet) from intersections or meet above exemptions	0

4.2.3.4 Center Stations

BRT corridors having single center stations assists in serving passengers of both directions easily which reduces the construction as well as right-of-way costs. BRT Standards award higher score to the centrally designed stations, and fewer points to physically separated stations serving single direction. The scoring criteria is shown in Table 4.54. There are centrally designed stations in BRT Peshawar serving both directions and therefore achieved 2/2 score.

Table 4.54 Scoring criteria for center stations (ITDP, 2016)

Center Stations	POINTS
>80% of stations on corridor have center platforms serving both directions of service	2
>50% of stations on corridor have center platforms serving both directions of service	1
>80% and above of stations on corridor have center platforms serving only one direction of service (e.g., Lanzhou BRT, see figure below)	1

4.2.3.5 Pavement Quality

Pavement quality plays an important role in determining users satisfaction of ride quality over the roads. The pavement having good quality serves for longer period by offering better operations and services minimizing rehabilitation and maintenance costs on busway. On the other hand, busway pavements with poor quality are often closed for maintenance, and provides poor quality ride to users which subsequently effect the quality and ridership of buses. The scoring criteria for the criteria is shown in Table 4.55. The corridor of BRT Peshawar is newly constructed, and has a good quality pavement which meet the criteria of pavement design for thirty years. This, it achieved 2/2 score in this element.

Table 4.55 Scoring criteria for pavement material (ITDP, 2016)

Pavement Materials	POINTS
Pavement structure designed for thirty-year life over entire corridor	2
Pavement structure designed for thirty-year life only at stations and intersections	1
Pavement structure designed for thirty-year life, except at stations and intersections	1
Pavement design life less than thirty years	0

4.2.4 Stations

Stations in the urban scheme provide space for the alighting and boarding passengers, and space for off-board collection of fare. The stations designed as per international standards improve the quality as well as user satisfaction of the scheme. The scoring is based on various components including inter-station distance, comfortable and safe stations, doors on buses, substops and docking bays, and sliding doors at BRT stations. BRT Peshawar scored 8/10 in station criteria which depicts that stations are designed according to international standards. The components are discussed in detail in following sections.

4.2.4.1 Distance between Stations

BRT Standards has specified the average distance of 0.3 to 0.8 km between stations which is reasonable for passengers to walk to stations, and also for maintaining bus speed. The scoring criteria is shown in Table 4.56. BRT Peshawar has achieved 0/2 score in this criteria as the average distance between stations is 0.85 kilometers which is greater than 0.8 kilometers.

Table 4.56 Scoring criteria for inter-station distance (ITDP, 2016)

Distance Between Stations	POINTS
Stations are spaced, on average, between 0.3 kilometers (0.2 miles) and 0.8 kilometers (0.5 miles) apart	2

4.2.4.2 Safe and Comfortable Stations

The stations must provide comfortable and safe services to the daily users to enhance the quality of BRT. The stations should be wide enough to accommodate passengers easily with the minimum width of 3 meters. It should provide protection against adverse weather conditions like rain, wind, cold, heat, and snow etc. There should be features of safety and attractiveness at stations to enhance quality as well as ridership of buses. The scoring criteria is shown in Table 4.57. The stations of BRT Peshawar are having width of greater than 3 meters, and also weather protected, safe and attractive which meets the criteria of BRT Standards. Therefore, it achieved a score of 3/3 in this element.

Table 4.57 Scoring criteria for stations (ITDP, 2016)

Stations	POINTS	WEIGHTED BY
Stations have all four elements	3	% of stations
Stations have three elements	2	
Stations have two elements	1	
Stations have one element	0	

4.2.4.3 Number of Doors on Buses

The delays and travel time can be reduced by introduction of multiple doors in buses to ease the boarding and alighting passengers. The scoring criteria is shown in Table 4.58. BRT Peshawar has articulated buses that only runs on main corridor are provided with three doors on station side. While in non-articulated buses, two doors are provided on station side to serve passengers of main corridor, and 3 doors are provided on other side to serve passengers of feeder routes. Thus, it scored 3/3 in doors criteria of buses.

Table 4.58 Scoring criteria for doors in buses (ITDP, 2016)

Stations	POINTS	WEIGHTED BY
Buses have at least three Doors (for articulated buses) or two Wide Doors (for non-articulated buses) on the Station Side. System allows boarding at all doors.	3	% of buses using corridor infrastructure meeting criteria

4.2.4.4 Docking Bays and Substops

Multiple substops and docking bays not only saves user time but it also enhance the capacity as well as level of service of the stations. The substops allow buses to pass the station and stop at the adjacent station separated by a walk way while docking bays allow buses to pull up behind the bus already standing at the station. There should be atleast two substops or docking bays at the station to avoid congestion and save user time. The scoring criteria is shown in Table 4.59. BRT Peshawar scored 1/1 in the aforementioned criteria as there are three docking bays at stations.

Table 4.59 Scoring criteria for substops and docking bays (ITDP, 2016)

Docking Bays and Substops	POINTS
At least two substops or docking bays at the highest-demand stations	1
Less than two substops or docking bays at the highest-demand stations	0

4.2.4.5 Sliding Doors in BRT Stations

Sliding doors enhance the quality of environment as well as the aesthetics of stations. It prevents passengers from adverse weather conditions, and increase the safety of stations. The scoring criteria is shown in Table 4.60. BRT Peshawar scored 1/1 as there are sliding doors at all stations.

Table 4.60 Scoring criteria for sliding doors (ITDP, 2016)

Sliding Doors	POINTS
All stations have sliding doors	1
Otherwise	0

4.2.5 Communications

It is the guidance of passengers regarding the required information about bus service which increases the quality and performance of the service. The scoring criteria is based on two components including passenger information and branding. BRT Peshawar scored 5/5 in the communication criteria. The two components are discussed in following sections.

4.2.5.1 Branding

Branding plays an important role in acceptance and enhancing the ridership of service by differentiating the service from other competitive services. The BRT buses should have a unique identity and brand to have a higher quality service. The scoring criteria is shown in Table 4.1. BRT Peshawar has buses of green color which differs it from other transport services that depicts one brand. While physical segregation and dedicated corridor that prevents corridor from other vehicles, represents one brand. Therefore, it scored 3/3 in the criteria of branding.

Table 4.61 Scoring criteria of branding (ITDP, 2016)

Branding	POINTS
All buses, routes, and stations in corridor follow single unifying brand of entire BRT system	3
All buses, routes, and stations in corridor follow single unifying brand, but differ from rest of system	2
Some buses, routes, and stations in corridor follow single unifying brand, regardless of rest of system	1
No corridor brand	0

4.2.5.2 Passenger Information

Real time information assists in guidance of passengers regarding departure and arrival of buses at both stations and buses which operates through GPS data. On the other hand, static passenger information provides guidance about vehicle and station signage, route maps, network maps etc. The scoring criteria is shown in Table 4.62. BRT Peshawar has achieved 2/2 score in this criteria as there will be provided real time and static information to passengers at stations and buses.

Table 4.62 Scoring criteria for passenger information (ITDP, 2016)

Passenger Information (at Stations and on Vehicles)	POINTS
Functioning real-time and up-to-date static passenger information corridor-wide	2
Up-to-date static passenger information	1

4.2.6 Access and Integration

BRT Standards has divided the scoring of this criteria into various components including universal access, integration with public transport, pedestrian safety and access, bicycle lanes, and bicycle sharing. BRT Peshawar scored 11/15 in this criteria which depicts that further attention is required to improve the quality and service of BRT Peshawar. The various components are discussed in detail in following sections.

4.2.6.1 Universal Access

Accessibility should be provided to all passengers of special needs including visually, physically and hearing impaired person. Physical accessibility should be provided at fare gates, vehicles and stations for disabled person with wheelchairs. Audiovisual accessibility is provided for visually impaired passengers including tactile surface indicators and Braille readers at stations to safely move through stations. The scoring criteria is shown in Table 4.63. BRT Peshawar has provided physical and audiovisual accessibility by providing lifts, escalators and tactile surface indicators at all stations. It scored 3/3 in this element.

Table 4.63 Scoring criteria for universal accessibility (ITDP, 2016)

Universal Accessibility	POINTS
Full accessibility provided	3
Physical accessibility provided	2
Audiovisual accessibility provided	1

4.2.6.2 Integration with Other Public Transport

Integration of BRT service with existing transport system is vital to increase the quality and ridership of the service. The distance of transferring points between modes should be minimum in order to reduce travel time and delays. It should also include fare integration where one fare system is used for various modes. The scoring criteria is shown in Table 4.64. BRT Peshawar is physically integrated, but there is not fare integration with existing transport. Therefore, it scored 2/3 in this component.

Table 4.64 Scoring criteria for integration with public transport (ITDP, 2016)

Integration with Other Public Transport	POINTS
Integration of both physical design and fare payment	3
Integration of physical design or fare payment only	2
No integration	0

4.2.6.3 Pedestrian Access and Safety

Stations should provide safe accessibility to pedestrians in order to achieve the goals and to have an increased level of service. Accessibility can be provided through bridges and underpasses with elevators or escalators, and at-grade crossings with signal and without signals etc. The scoring criteria is shown in Table 4.65. BRT Peshawar provides safe pedestrian access to all stations, and pedestrian bridges are provided at most of stations as it is built in the center of road which increase the safety of the service. While at some stations, pedestrians have to cross the road and modest improvements are provided along corridor. So, it scored 3/4 in this component.

Table 4.65 Scoring criteria for pedestrian access (ITDP, 2016)

Pedestrian Access	POINTS
Good, safe pedestrian access at every station and many improvements along corridor	4
Good, safe pedestrian access at every station and modest improvements along corridor	3
Good, safe pedestrian access at every station and no other improvements along corridor	2
Good, safe pedestrian access at most stations and no other improvements along corridor	1
Stations lack good, safe pedestrian access	0

4.2.6.4 Secure Bicycle Parking

Secure parking for bicycles should be provided to enhance the system coverage and quality, and reduce travel time of passengers to access the corridor. The scoring criteria is shown in Table 4.66. .BRT Peshawar will provide secure parking for bicycles monitored by cameras, and therefore scored 2/2 in this criteria.

Table 4.66 Scoring criteria for bicycle parking (ITDP, 2016)

Bicycle Parking	POINTS
Secure bicycle parking at least in higher-demand stations and standard bicycle racks elsewhere	2
Standard bicycle racks in most stations	1
Little or no bicycle parking	0

4.2.6.5 Bicycle Lanes

Bicycle lanes in BRT corridor provides sustainable way of travel improving passengers access and road safety. The scoring criteria is shown in Table 4.67. BRT Peshawar has bicycle lanes at some sections and do not span the entire corridor. So, it scored 1/2 in this criteria.

Table 4.67 Scoring criteria for bicycle lanes (ITDP, 2016)

Bicycle Lanes	POINTS
Bicycle lanes on or parallel to entire corridor	2
Bicycle lanes do not span entire corridor	1
Poorly-designed or no bicycle infrastructure	0

4.2.6.6 Bicycle Sharing Integration

Sharing bicycle provides an opportunity in making short trips from corridor which increases the access to most of destinations. It can be seen as the low cost best alternative for feeder busses which reduces passenger travel time and increases the coverage of transportation system. The scoring criteria is shown in Table 4.68. BRT Peshawar scored 0/1 in this criteria as there will be bicycle sharing at less than 50% of the stations.

Table 4.68 Scoring criteria for bicycle sharing (ITDP, 2016)

Bicycle-Sharing Integration	POINTS
Bicycle-sharing at minimum of 50% of stations on corridor	1
Bicycle-sharing at <50% of stations on corridor	0

The summarized results of evaluation of BRT by comparison with BRT Standards 2016 are presented in Table 4.69.

Table 4.69 Summarized results of BRT Peshawar comparison with BRT Standards 2016

BRT Standards	BRT Standards 2016	BRT Peshawar Achieved Points
BRT Basics	**38**	**38**
Dedicated Right-of-Way (Minimum 4 Points)	8	8
Busway Alignment (Minimum 4 Points)	8	8
Off-board Fare Collection	8	8
Intersection Treatments	7	7
Platform-level Boarding	7	7
Service Planning	**19**	**16**
Multiple Routes	4	4
Express, Limited-Stop, and Local Services	3	3
Control Center	3	3
Located In Top Ten Corridors	2	2
Demand Profile	3	3
Hours of Operation	2	1
Multi-Corridor Network	2	0
Infrastructure	**13**	**10**
Passing Lanes at Stations	3	0
Minimizing Bus Emissions	3	3
Stations Set Back from Intersections	3	3
Center Stations	2	2
Pavement Quality	2	2
Stations	**10**	**8**
Distances Between Stations	2	0
Safe and Comfortable Stations	3	3
Number of Doors on Bus	3	3
Docking Bays and Substops	1	1
Sliding Doors in BRT Stations	1	1
Communications	**5**	**5**
Branding	3	3

Passenger Information	2	2
Access and Integration	**15**	**11**
Universal Access	3	3
Integration with Other Public Transport	3	2
Pedestrian Access and Safety	4	3
Secure Bicycle Parking	2	2
Bicycle Lanes	2	1
Bicycle-Sharing Integration	1	0
Total	**100**	**88**
Classification of BRT Peshawar	**Gold, silver, bronze**	**Gold**

The graphical representation of comparison of BRT Peshawar with the BRT Standards 2016 is shown in Figure 4.12. The scoring of six elements and total score is graphically represented.

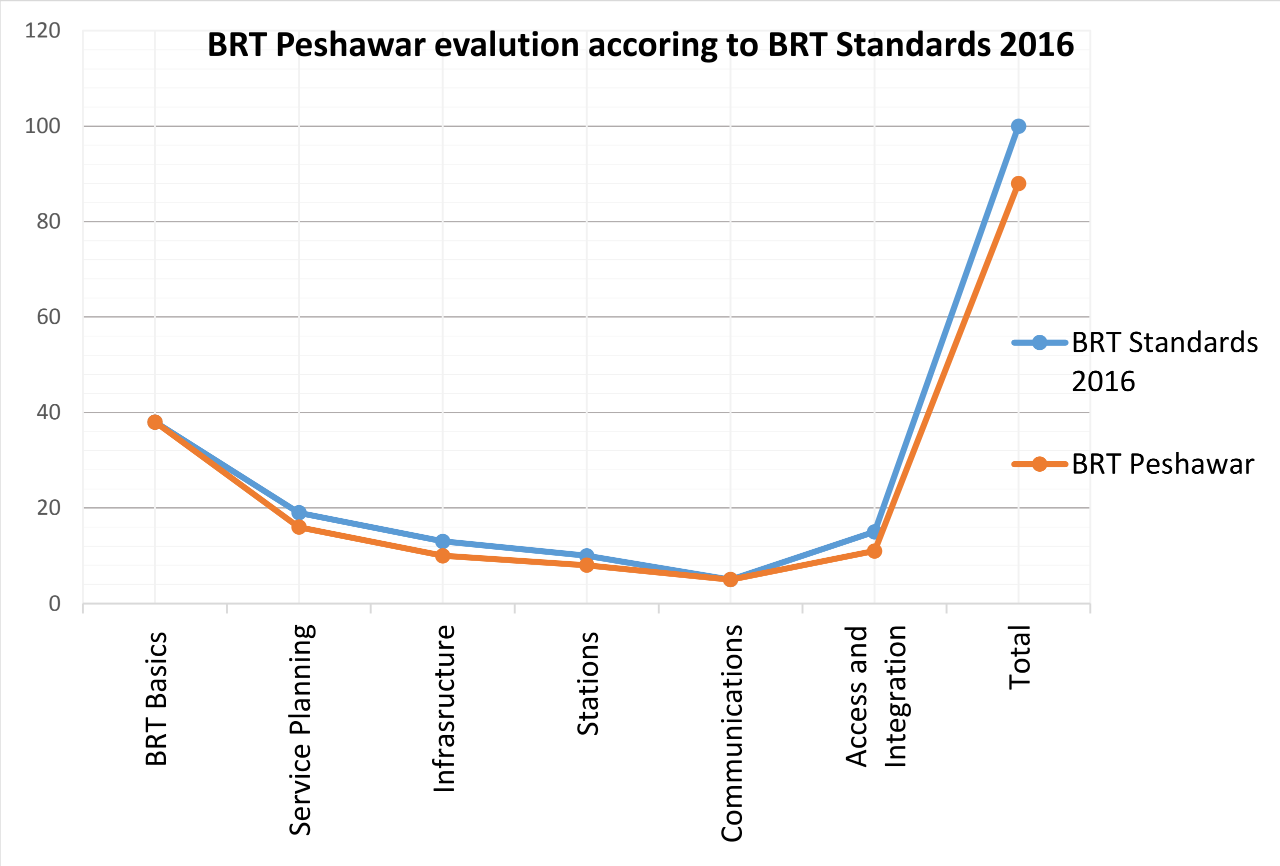

Figure 4.12 BRT Peshawar comparison with BRT Standards 2016

BRT Standards 2016 has categorized the scoring criteria into three categories: Gold, silver, and bronze categories. Gold, silver, and bronze standard is awarded to BRT if it scores 85-100, 70-84.9, and 55-69.9 points in BRT Standards 2016 respectively. BRT Peshawar achieved “Gold-Standard” as it scored 88 out of 100 by comparison with BRT Standards 2016 as shown in Table 4.69. It can be seen that there is improvement required in some areas like service planning, infrastructure, and access and integration to upgrade the BRT service in order to achieve good passenger satisfaction, ride quality, and increase in ridership of service.

CHAPTER 5

5. CONCLUSION AND RECOMMENDATIONS

Public transport is the important means of transportation in urban areas to move passengers from one place to another with increased capacity and reduced travel time sharing common transit service. These urban schemes provide the economical way of travel to all walks of life. The government of Pakistan is looking towards most sustainable, economic and safe urban transportation schemes that has good effects on surrounding and environment. Therefore, it has initiated BRT projects in different metropolitan cities of Pakistan. The evaluation of such schemes is necessary in order to know the success and achievement of goals for which they were implemented. This research study has evaluated BRT Peshawar on it's potential to attract commuters pertaining to private modes of car, motorcycle and taxi, and also compared the scheme with the international standards followed around world such as "BRT Standards 2016".

5.1 Conclusion

This research study has assessed the commuter current modal choices and their potential of shift towards BRT Peshawar by using revealed and stated preference survey. Data is comprised of socio-economic characteristics of respondents (gender, age, trip purpose, travel time, speed cycles, and vehicle operating cost) about current mode of travel, and preferred modes when BRT becomes operational. Separate binary logit models were introduced for three modes (owned car, motorcycle, and taxi) for modelling commuters potential of shift from current modes to BRT Peshawar. The models were developed based on three service attributes (travel time, speed cycles, and vehicle operating cost) that truly explain the variation in modal shifts from current private modes towards BRT. Models statistics revealed that they were statistically significant showing goodness of fit.

The calibrated binary logit models predicted that the travel time and vehicle operating costs significantly affect the modal shifts of BRT Peshawar. The service attribute that influenced the shifts of taxi and motorcycle was travel time while for car was vehicle operating cost. The congestion on main road of Peshawar has increased to such an extent that road network is often blocked with increased travel time that has significantly increased the vehicle operating cost. Therefore, users consider vehicle operating cost and travel time as governing factor that will compel them towards BRT Peshawar which is well predicted by model. It was found that BRT Peshawar has a potential to attract significant users of private modes. The taxi users have higher shift proportion as compared to commuters pertaining to motorcycle, and car to use BRT as a mode of journey. The analysis showed that commuters using current modes of bus, taxi, motorcycle, car, and other have showed willingness of 93.8, 59, 51.9, 33.8, and 79.17 percent towards BRT respectively.

This research study has also assessed the performance evaluation of the proposed BRT Peshawar. It was found satisfactory based on various elements, and achieved "Gold-Standard BRT" status as it scored 88 out of 100 while comparison with the international standards of "BRT Standards 2016". However, much improvement can be seen in some areas of BRT Peshawar to have a sustainable development in the business hub of CPEC. It has scored low in service planning, infrastructure, and access and integration elements which are the key components of the urban scheme. The deviation of proposed scheme from standards can lead towards failure of transportation system. The operating agencies should focus on the operational hours, multi-corridor network, passing lanes at stations, bicycle lanes, and integration of bicycle sharing for improving the service quality, user satisfaction, and increasing ridership of BRT Peshawar.

The research findings are helpful in determining that BRT Peshawar has a potential to attract significant commuters pertaining to current modes that will ultimately help to mitigate the current issues of congestion, carbon footprints, and traffic accidents in Peshawar city. This study will help operating agencies in planning, and developing strategies that will improve ridership and quality of BRT Peshawar by attracting significant proportion of users from current private modes to have a sustainable urban transportation system.

5.2 Recommendations

- The policy makers and operating agencies can take advantage of the models and implement policies that will attract significant proportion of users from private modes towards BRT Peshawar. It will ultimately reduce the current issues of congestion, carbon footprints, and safety.

- Passing lanes at the stations should be provided in order to reduce the delays and travel time. Passing lanes will permit the fully loaded buses to pass the bus standing at the station.
- Bicycle lanes should be provided throughout the corridor so that the sustainable way of travel is provided by increasing access and safety.
- The bicycle sharing should be integrated which provides an opportunity in making short trips from corridor that increases the access to most of destinations. It can be seen as the low cost best alternative for feeder buses which reduces passenger travel time and increases the coverage of transportation system.

5.3 Future Work

- The analysis of modal shares at the operational stage of BRT Peshawar.
- Inclusion of more service attributes in modal share analysis of BRT Peshawar.
- The study of effect of travel time on travel cost by having further study on individuals moving between origin and destination.
- The comparison of BRT Peshawar with BRT Standards after six months of operation of BRT.
- The modal share analysis of Multan Metro Bus Service.
- The comparison of Multan Metro Bus with the international standards.
- The comparison of Pakistan BRT Services with the other countries.
- Safety study in mass transportation.
- Study on transit operations for individuals with disabilities.
- Integrated mass transportation of BRT with other modes.

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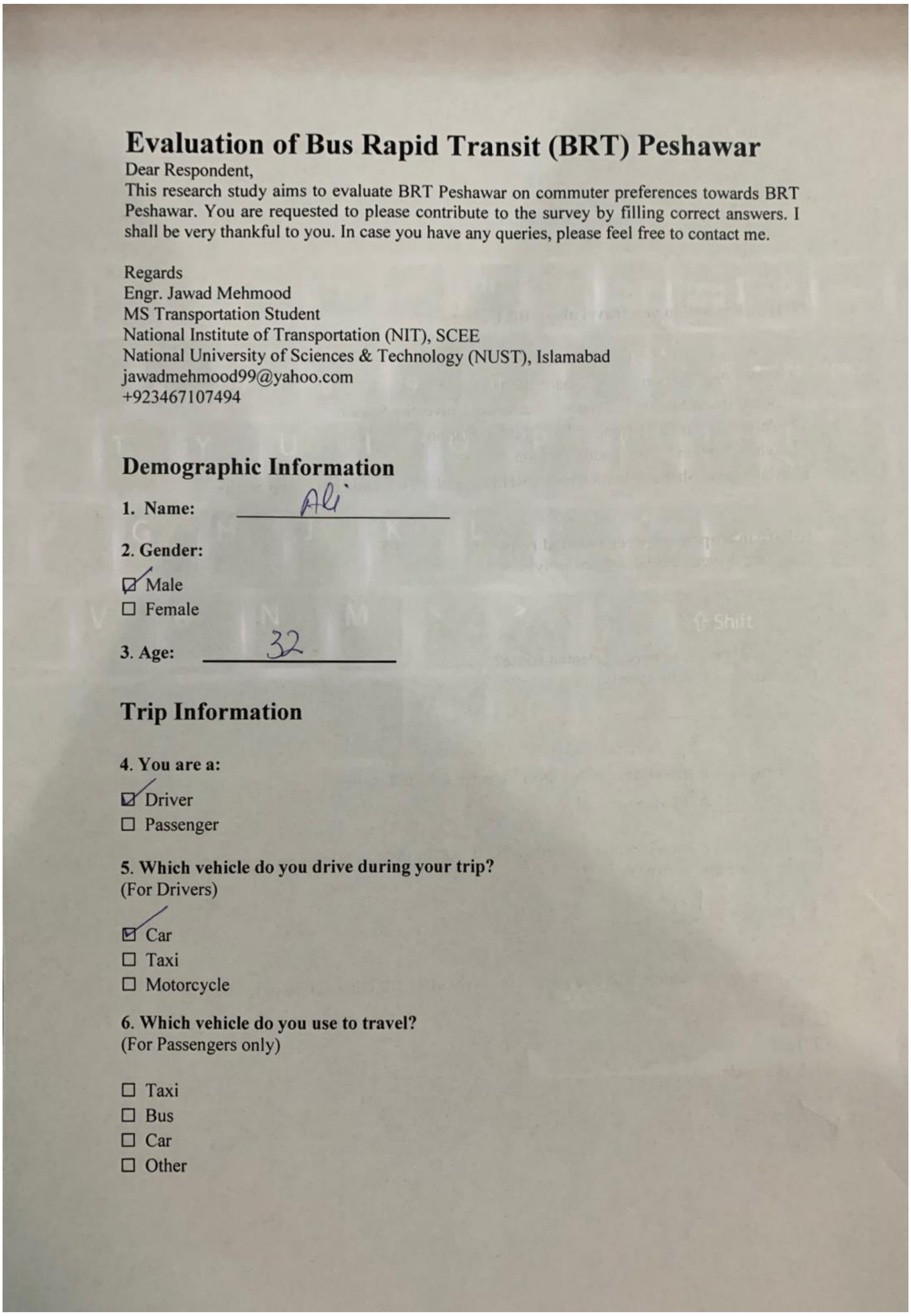
APPENDIX

APPENDIX-I

Questionnaire Survey Form 1



Evaluation of Bus Rapid Transit (BRT) Peshawar

Dear Respondent,

This research study aims to evaluate BRT Peshawar on commuter preferences towards BRT Peshawar. You are requested to please contribute to the survey by filling correct answers. I shall be very thankful to you. In case you have any queries, please feel free to contact me.

Regards
Engr. Jawad Mehmood
MS Transportation Student
National Institute of Transportation (NIT), SCEE
National University of Sciences & Technology (NUST), Islamabad
jawadmehmood99@yahoo.com
+923467107494

Demographic Information

1. Name: Ali

2. Gender:

- ☑ Male
- ☐ Female

3. Age: 32

Trip Information

4. You are a:

- ☑ Driver
- ☐ Passenger

5. Which vehicle do you drive during your trip?
(For Drivers)

- ☑ Car
- ☐ Taxi
- ☐ Motorcycle

6. Which vehicle do you use to travel?
(For Passengers only)

- ☐ Taxi
- ☐ Bus
- ☐ Car
- ☐ Other

7. What is your purpose of trip?

- ☐ School/University
- ☑ Work
- ☐ Recreational
- ☐ Shopping
- ☐ Other

8. Which route do you travel along BRT corridor?

- ☐ Karkhano Station To PDA Station
- ☐ Tatara Park Station To Board Bazar Station
- ☐ Board Bazar Station To Peshawar University Station
- ☐ University Town Station To Tehkal Station
- ☐ Tehkal Station To Saddar Station
- ☑ Malik Saad Shaheed Station near LRH Hospital To Old Haji Camp Station

9. Fare in Rupees between selected route?
(For Taxi drivers and Passengers only)

____

10. Cost of travel between selected route?
(For Motorcycle drivers only)

____

11. What is you travel time in minutes between selected route?

24 minutes

12. How many speed cycles (Number of times brakes applied) are usually involved between selected route?

35

13. Which mode/vehicle will you prefer to travel after BRT becomes operational?

- ☐ Car
- ☐ Taxi
- ☐ Motorcycle
- ☐ Bus
- ☑ BRT Bus
- ☐ Other

Questionnaire Survey Form 2

Evaluation of Bus Rapid Transit (BRT) Peshawar

Dear Respondent,

This research study aims to evaluate BRT Peshawar on commuter preferences towards BRT Peshawar. You are requested to please contribute to the survey by filling correct answers. I shall be very thankful to you. In case you have any queries, please feel free to contact me.

Regards

Engr. Jawad Mehmood
MS Transportation Student
National Institute of Transportation (NIT), SCEE
National University of Sciences & Technology (NUST), Islamabad
jawadmehmood99@yahoo.com
+923467107494

Demographic Information

1. Name: J.bran

2. Gender:

- [x] Male
- [ ] Female

3. Age: 22

Trip Information

4. You are a:

- [ ] Driver
- [x] Passenger

5. Which vehicle do you drive during your trip?
(For Drivers)

- [ ] Car
- [ ] Taxi
- [ ] Motorcycle

6. Which vehicle do you use to travel?
(For Passengers only)

- [ ] Taxi
- [x] Bus
- [ ] Car
- [ ] Other

7. What is your purpose of trip?

- ☑ School/University
- ☐ Work
- ☐ Recreational
- ☐ Shopping
- ☐ Other

8. Which route do you travel along BRT corridor?

- ☐ Karkhano Station To PDA Station
- ☑ Tatara Park Station To Board Bazar Station
- ☐ Board Bazar Station To Peshawar University Station
- ☐ University Town Station To Tehkal Station
- ☐ Tehkal Station To Saddar Station
- ☐ Malik Saad Shaheed Station near LRH Hospital To Old Haji Camp Station

9. Fare in Rupees between selected route?
(For Taxi drivers and Passengers only)

____

10. Cost of travel between selected route?
(For Motorcycle drivers only)

____

11. What is you travel time in minutes between selected route?

15 mins

12. How many speed cycles (Number of times brakes applied) are usually involved between selected route?

____

13. Which mode/vehicle will you prefer to travel after BRT becomes operational?

- ☐ Car
- ☐ Taxi
- ☐ Motorcycle
- ☐ Bus
- ☑ BRT Bus
- ☐ Other

Questionnaire Survey Form 3

Evaluation of Bus Rapid Transit (BRT) Peshawar

Dear Respondent,

This research study aims to evaluate BRT Peshawar on commuter preferences towards BRT Peshawar. You are requested to please contribute to the survey by filling correct answers. I shall be very thankful to you. In case you have any queries, please feel free to contact me.

Regards
Engr. Jawad Mehmood
MS Transportation Student
National Institute of Transportation (NIT), SCEE
National University of Sciences & Technology (NUST), Islamabad
jawadmehmood99@yahoo.com
+923467107494

Demographic Information

1. Name: Aaisha Akbar

2. Gender:

- ☐ Male
- ☑ Female

3. Age: 19

Trip Information

4. You are a:

- ☐ Driver
- ☑ Passenger

5. Which vehicle do you drive during your trip?
(For Drivers)

- ☐ Car
- ☐ Taxi
- ☐ Motorcycle

6. Which vehicle do you use to travel?
(For Passengers only)

- ☑ Taxi
- ☐ Bus
- ☐ Car
- ☐ Other

7. What is your purpose of trip?

- ☐ School/University
- ☐ Work
- ☐ Recreational
- ☑ Shopping
- ☐ Other

8. Which route do you travel along BRT corridor?

- ☐ Karkhano Station To PDA Station
- ☐ Tatara Park Station To Board Bazar Station
- ☐ Board Bazar Station To Peshawar University Station
- ☐ University Town Station To Tehkal Station
- ☑ Tehkal Station To Saddar Station
- ☐ Malik Saad Shaheed Station near LRH Hospital To Old Haji Camp Station

9. Fare in Rupees between selected route?
(For Taxi drivers and Passengers only)

Rs.100

10. Cost of travel between selected route?
(For Motorcycle drivers only)

____

11. What is you travel time in minutes between selected route?

20 minutes

12. How many speed cycles (Number of times brakes applied) are usually involved between selected route?

____

13. Which mode/vehicle will you prefer to travel after BRT becomes operational?

- ☐ Car
- ☐ Taxi
- ☐ Motorcycle
- ☐ Bus
- ☑ BRT Bus
- ☐ Other

APPENDIX-II

Defence Questions

Q 1: Why two distinct projects are combined in one research study?

Refer to page 4 and 5.

Q 2: Why the male and female data are incorporated?

Refer to page 27.

Q 3: What are speed cycles, and how the data was collected?

Refer to page 39 and 40.

Q 4: Why users of bus have showed more willingness to shift towards BRT service?

Refer to page 36 and 37.

Q 5: What is universal access?

Refer to page 66 and 67.

Q 6: What is pavement quality as per BRT Standards 2016?

Refer to page 61 and 62.