Bus Rapid Transit:

Mode Shift and Environmental Impact Analysis.

A Case Study of Rawalpindi-Islamabad Metro Bus Service.

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2017

Bus Rapid Transit:
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Thesis Submitted In Partial Fulfillment of the Requirement for the Degree of

Master of Philosophy in Environmental Economics

To

DEPARTMENT OF ENVIRONMENTAL ECONOMICS

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10/M.Phil-Env/PIDE/2015

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2017

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CERTIFICATE

This is to certify that this thesis entitled: **"Bus Rapid Transit: Mode Shift and Environmental Impact Analysis. A Case Study of Rawalpindi-Islamabad Metro Bus Service"**, submitted by Rehana Ali Naqvi is accepted in its present form by the Department of Environmental Economics, Pakistan Institute of Development Economics (PIDE), Islamabad as satisfying the requirements for partial fulfillment of the degree in **Master of Philosophyin Environmental Economics**.

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Dedication

Every challenging work needs self-effort as well as guidance of elders specially those who are very close to our heart.

My humble effort I dedicate to my sweet and loving

Father & Mother

Whose affection, love and encouragement make me able to get such success and honor.

Acknowledgement

Prima facie, I am grateful to Allah Almighty for the wisdom He bestowed upon me, the strength, peace of mind and good health in order to finish this research.

I wish to express my sincere gratitude to my supervisor Dr. Muhammad Irfan for continuous support of my research, for his motivation, enthusiasm and immense knowledge. His guidance helped me in all the time of research and writing of this thesis.

I place on record, my sincere thanks to Dr. Rehana Siddiqui, Head of Department for the continuous encouragement. I am extremely thankful and indebted to her for sharing expertise, and sincere and valuable guidance extended to me.

I take this opportunity to express gratitude to all of the Department faculty members for their comments that greatly assisted the research and improved the manuscript.

Finally, I must express my very profound gratitude to my parents and to my siblings for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without them.

I also place on record, my sense of gratitude to one and all, who directly or indirectly, have lent their hand in this venture.

Thank you very much, everyone!

Rehana Ali Naqvi

Declaration

I, Rehana Ali Naqvi, 10/M.Phil-Env/PIDE/2015 declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research. I also declare that I have not taken any material from any source except referred to wherever due that amount of plagiarism is within acceptable range. If a violation of HEC rules on research has occurred in this thesis. I shall be liable to punishable action under the plagiarism rules of the HEC.

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ABSTRACT

Transportation is considered as the fundamental factor for mobility as every individual is highly dependent on transportation so that they have access to jobs, goods and other services. Increasing demand for motorization is causing congestion issues in quickly growing urban communities. Islamabad, capital city of Pakistan, along with its neighboring city Rawalpindi initiated a metro bus service to ease the traffic congestion problem and to reduce the atmospheric pollution. This study aimed to analyze the mode shift behavior of commuters from public transport, own transport and taxi after the implementation of metro bus service. The study used logistic regression because the dependent variable is binary in nature. Secondly, the study was aimed to find out the carbon emissions reduced after the launch of metro bus service in the region. The results of the study indicated that commuters are more willing to shift towards metro bus for job and education purpose. Female travelers are more willing to use metro bus service as compared to males. Income shows no effect on mode shift behavior. The study also found that metro bus has the potential to reduce travel cost of around PKR 1000 per month and travel time of around 23 minutes per month. Lastly it found that metro bus service has the potential to clean the environment by reducing carbon emissions, as it replaced approximately 700 public vehicles from the route, resulting in the reduction of around 8000 metric tons of carbon emissions from the region.

Keywords: Metro bus service; Logistic regression model; Mode shift behavior; Carbon emissions

Chapter 1

INTRODUCTION

Rapid urbanization in developing nations is causing many rural citizens to migrate towards urban areas to explore job opportunities and for better facilities. Along with urbanization, transportation is also increasing instantly due to the fact that it is considered as the fundamental factor in urbanization. Every individual is highly dependent on transportation as it provides mobility to population so that they have access to jobs, goods and services and what they need and want (Deborah and Aligula, 2012). Expanding urban population and motorization are causing adverse effects on urban ecosystem. Increasing demand for motorization is causing congestion issues in quickly growing urban communities (UN-Habitat, 2012). Subsequently, congestion is a noteworthy issue, as lot of time is wasted in traffic. Traffic congestion causes numerous environmental issues too, categorically climate change and air pollution. Increasing rate of greenhouse gas (GHG) emanations, of which carbon dioxide (CO2) is most imperative, and assumed to result in more extreme weather patterns(heavier precipitation and increased drought) among other impacts (UN-Habitat, 2012).The transport sector is responsible for around 25% of global carbon dioxide (CO2) emissions (EEA, 2008). China and India are estimated to be responsible for 56% of the global increase in transport-related carbon emissions in the period 2005 to 2030.The share is likely to rise in the future with increasing growth in population and increased affluence in developing countries (Doll & Balaban, 2013). Deep cuts are needed in this sector to reach the emission targets set by the Intergovernmental Panel on Climate Change

(IPCC). IPCC states that “a 50% reduction in greenhouse gas (GHG) emissions by 2050 is required to limit global warming to below 2±C” (IPCC, 2014).

Across the globe, urban hubs are troubled with the irregular transportation patterns due to road congestion, noise pollution, and increased use of energy, air pollution and traffic accidents (Jain and Khare, 2010). Mitigating these serious traffic issues is becoming one of the main challenges faced by the all governments of the world. These issues are even more striking for developing cities, where the vehicular growth rate is much greater than the growth rate of transport infrastructure (Santos et al., 2010).

Like many other urban cities in Asia, Islamabad, capital city of Pakistan is also facing a prominent growth due to increased growth rate in population and migration. Islamabad is considered to be nucleus for economic, political and commercial activities, due to which many people attracted towards the city, which increases the demand for passenger transportation. People travel towards Islamabad for job and other economic activities on daily basis from the neighboring cities such as Rawalpindi, Taxila and Hasanabdal, which results in the increased reliance on personal vehicles.

Islamabad, capital city of Pakistan along with its twin city Rawalpindi is considered as the third biggest urban amalgamation in Pakistan having 4.5million population (Pakistan Bureau of Statistics, 2015). Around 525,000 passengers are carried by over 210,000 vehicles on three major corridors of the cities. The main mode of mobility between the cities is only through private transport. (Asian development Bank, 2012).

In order to trap these issues, Government of Pakistan introduced bus rapid transit in Islamabad- Rawalpindi region. By the introduction of an ecologically sustainable urban transport system and switching some of the transport to bus rapid transit system can help to arrest some serious issues. Metro bus service provides multiple benefits i.e. Reduction in traffic congestion, reduction in accidents, time saving to passengers, reduction in air pollution and fuel savings (Murty et al., 2006).

1.1: Overview of Bus Rapid Transit:

"Bus Rapid Transit (BRT) is a high-quality bus-based transit system that delivers fast, comfortable, and cost-effective services at metro-level capacities. It does this through the provision of dedicated lanes, with busways and iconic stations typically aligned to the center of the road, off-board fare collection, and fast and frequent operations".

BRT delivers a higher quality of service(comfortable journey, low fare, time efficient and congestion free ride) than customary urban transport operations in view of decreased waiting and travel times, expanded administration dependability and an improved user experience (Diaz et al., 2004)

First bus rapid transit built in Curitiba, a city in Brazil in 1974(Goodman et al., 2005; Lindau et al., 2010). Bogotá's TransMilenio also launched this service in 2000 in Colombia and then, numerous particularly Latin American cities have gone with the same pattern. The worldwide growth of bus rapid transit has been gigantic lately. Today more than 207 urban communities around the world have executed 5468kilometers of bus rapid transit which carry approximately 34,300,647 daily passenger trips (BRT data, 2016).

1.1.1: Bus Rapid Transit in Pakistan:

In Pakistan, metro is operating successfully in Lahore and in twin cities, Islamabad and Rawalpindi, having 50 kilometers of total length and carry 305,000 passengers per day (BRT data, 2016).

1.1.2: Bus Rapid Transit in Rawalpindi- Islamabad:

Islamabad, capital city of Pakistan along with its twin city Rawalpindi is considered as the third biggest urban amalgamation in Pakistan having 4.5million population. The main mode of mobility between the cities is only through private transport. There was no organized system of transportation in twin cities. Around 525,000 passengers are carried by over 210,000 vehicles on three major corridors of the cities (Asian Development Bank, 2012). During the last couple of years there has been an exceptional increment in vehicular activity which seriously effects urban ecosystem particularly because of increased rate atmospheric pollution and alterations in land use pattern. In order to trap these serious issues in the city, Federal government in collaboration with Punjab metro bus authority launched bus rapid transit system on June 2015 in Rawalpindi-Islamabad region. Metro bus provides several benefits which include reduced motor vehicle accidents, savings in operating costs and travel time and will help make a superior urban condition by reducing congestion and pollution. Environmentally, the bus rapid transit system has a tendency to supplant more than 15 million km wagons, autos and motorcycle travel every year. It will positively affect climate change by decreasing CO_2 discharge by more than 4,000 tons every year (Asian development bank, 2012).

1.2: Problem Statement:

With high level urbanization and rapid economic development, the problems caused by growing vehicle ownership and increasing urban population have resulted in some significant changes in travel behavior and serious traffic congestion in Islamabad. Like all other developing cities, Islamabad has also introduced metro bus service to change travel structure and to reduce traffic congestion. Before the launch of metro bus service, people traveled by public transport, own vehicles and some used taxi. A lot of time was wasted in traffic congestion and traveling expense also increased, but soon after the introduction of metro bus, travelers' mode shift behavior has emerged. They shift from their previous mode of travel towards metro bus. The main reason of travelers attraction towards metro is that metro has a separate, congestion free route, so travel time is reduced, low fare is charged and a comfortable and a secure ride is provided to them.

This study tends to analyze the perception of commuters of metro bus service in order to estimate travel cost, travel time reduction due to metro bus service and identifies the priorities of commuters for using metro bus service. In order to assess the perceptions and priorities of commuters for choosing metro mode, an extensive field survey is conducted on various stations of Islamabad-Rawalpindi metro bus service. It further assesses the overall impact of mode split changes due to the deployment of metro bus service. Due to urbanization, transportation is also increasing dramatically and hence air pollution is also rising. From environment point of view, metro bus has replaced around 700 public vehicles from the route, as a result, a significant amount of carbon emission are reduced from the city.

1.3. Objectives of the Study:

By taking into account the above discussion, this study has the following objectives:

- To investigate the mode shift behavior of commuters from public transport, own transport and taxi towards metro bus service.
- To estimate the savings in travel cost and travel time of commuters of metro bus service.
- To evaluate the carbon emissions saved due to launch of metro bus service in the city.

1.4. Research Questions:

- What are the reasons behind the frequent use of metro bus service?
- How much travel cost and travel time is reduced due to launch of metro bus service?
- How much carbon emissions are reduced due to launch of metro bus service in the city?

1.5: Significance of the Study:

Transport activity is considered as the leading part of economic development and human well- being. With an increase in economies, transportation is also rising around the globe. Growing motorization is causing severe impacts such as traffic congestion, air pollution, traffic fatalities and petroleum dependence. These issues are quite acute in developing countries like Pakistan. Metro bus service is launched to capture these serious issues. This study assesses the mode shift behavior of commuters towards metro bus service. On the other hand, this study has contributed to the literature in environment in the context of Pakistan by explaining impact on environment by estimating the amount of carbon emissions which are reduced due to launch of metro bus service in twin cities.

The entire study is divided into five sections. Chapter 1 is composed of introduction. Literature review is included in chapter 2, while chapter 3 included the description of study area. Chapter 4 discusses the methodology along with empirical model used and details of variables. Results and discussions are included in chapter 5 and lastly chapter 6 includes conclusion and recommendations.

Chapter 2

LITERATURE REVIEW

Transportation is considered as the fundamental factor in human society. Every individual is highly dependent on transportation, as it provides mobility to population so that they have access to jobs, goods and services and what they need and want (Salon, 2012). Urban ecosystem is adversely affected due to increased demand for public transport. Road congestion and atmospheric pollution are becoming serious issues in transport sector. Mass transit system has the potential to mitigate congestion by offering a more efficient mobility of individuals. Curitiba, a city in Brazil has launched the Bus Rapid Transit (BRT) service in 1974. Bogotá's TransMilenio also launched this service in 2000 and then, numerous particularly Latin American cities have gone with the same pattern. Bus rapid transit provides multiple benefits to its passengers i.e. Reduction in traffic congestion, reduction in accidents, time saving to passengers, reduction in air pollution and fuel savings (Murty et al., 2006). Some of these benefits are discussed in the following literature review.

2.1. Reduction in Air Pollution:

Following literature shows that bus rapid transit reduces air pollution. Salehi et al. (2016) evaluated the positive as well as negative impacts of metro bus on environment. Results of the study revealed that fuel consumption is reduced to approximately 6.5 million liters annually. 29450 taxis left the route and around 8 thousand tons of various air pollutants i.e. CO, NO, NOx and SO2 are reduced due to the launch of bus rapid transit in Tehran. Negative impacts includes biological loss such as cutting of trees from the route and it is also noted that many shopkeepers lose their income since BRT route set restriction for car parking along the route.

Delhi is the most motorized Indian city where automobile and two-wheeler population have expanded 60 fold and 200fold respectively between 1957 and 2002. It is revealed that 22% and 25% of current metro users are former car and two-wheeler users respectively. Model shift from private modes to metro system reduced around 2.3% of carbon emissions from Delhi (Thynell et al., 2010; Badami and Haider, 2007). Sharma et.al (2014) evaluated the amount of carbon emissions saved due to launch of metro bus in Delhi. In order to estimate the amount of carbon emission saved, metro ridership is converted to number of vehicles shifted (from roads) by utilizing data on average trip length, occupancy and number of kilometers travelled by different vehicles. Results of this study show that around 23111 vehicles in year 2006 and 110 954 vehicles in year 2011were replaced because of the fact that large group of commuters are now using metro rail instead of road transport. Estimation and sensitivity analysis indicate that amount of carbon emissions which have been saved/ reduced are nearly 1882 tons in year 2006 to nearly 7120 tons during the span of one year. Doll and Balaban, (2013) have evaluated environmental co-benefits that are generated by Delhi metro. Delhi metro has become the first ever rail project in the world which receives carbon credits under the Clean Development Mechanism of the United Nations Framework Convention on Climate Change . As per the estimations and calculations made by Delhi Metro Rail Corporation (DMRC), it has reduced emissions by 41,160 tons of CO2 equivalent per annum between 2007 and 2017, and its total estimated emissions reductions by 2017 would be 411,600tonnes of CO2 equivalent (UNFCCC, 2007).

According to Turner et al. (2012) in Bogota nearly one million tons of carbon is reduced per year. Around 40,000 carbon emission are reduced annually in Johannesburg due to introduction of metro (Jiice, 2012). In Mexico 27000 tons of carbon emissions are reduced (INE, 2006) and in Istanbul 167tons of carbon emissions are reduced daily (Alpkokin & Ergun, 2012). Benefits are greater than cost in all of the four bus rapid transits presented in the case study and they also have positive net present benefits. Internal rate of return indicates each of the investments was at least as socially profitable as the opportunity cost of public (Carrigan et al., 2014).

Murty et al. (2006) has taken the 2 phases i.e. phase 1 and phase 2 of Delhi metro service, having a length of 108 kilometer to measure costs and benefits. According to this study, accounting for benefits from the reduction in urban air pollution in Delhi due to metro has increased the economic rate if return to 23.9%. This means that benefits to Delhi public from reduced air pollution due to launch of metro increases its economic rate of return by 1.4%. Levinson et al.(2013) have found out that with the launch of metro bus, around 80,000 vehicles reduced from the road and hence 623 tons of CO_2 is reduced on daily basis.

2.2: Reduction in Travel Time and Travel Cost:

Metro also reduces travel time and travel cost. Domencich et al. (1968) evaluated the elasticities of demand for public transport in connection to all parts of cost and time. They found that traveler demand has diminished by 3.9 percent for a 10 percent expansion in travel time, while demand has decreased by 7 percent for each of the 10 percent increment in egress, waiting time and access. These discoveries were accounted for and approved later by Kraft and Domencich (1972) and O'Sullivan (2000).

Levinson et al. (2013) have analyzed metro bus system in Istanbul, Turkey. This study has focused mainly on the passengers' attitude towards metro bus. Survey has been conducted to assess the ridership trends, rider demographics and change in model shift. It also provides benefits which are achieved due to introduction of metro bus service in Istanbul. Results revealed that with the launch of metro bus, around 80,000 vehicles reduced from the road and hence 623 tons of CO_2 is reduced on daily basis. From passengers point of view around 61% of travel cost is reduced and 52 minutes daily (316 hour/year) are saved and hence 90% passengers are satisfied by its service.

Golias (2002) has found in the study that passengers of metro bus service in Athens are quite sensitive to change in travel cost than travel time. From ridership view point, metro bus system in Athens has pulled in 53% of transport riders and 24% of private transport users. Multinomial probit model and hierarchical extreme value logit models have been used in this paper. Elasticities related to mode choice have shown that passengers who use metro bus service are oversensitive to changes in travel cost as compared to the travel time.

Wang et al. (2013) have examined the mode shift behavior of different transport users (auto, taxi, bicycle and bus) after the implementation of metro bus system in Xi'an, China. This study has used logistic model to estimate choice probabilities. Results have revealed that 66.7% passengers of metro bus system were shifted from local/public transport and around 20.6% of the passengers were using private transportation before the launch of metro bus. Furthermore, according to the passengers, approximately 13 minutes were also saved by using metro bus system and these passengers further revealed that they also save approximately 4dollars by using metro bus service. Around 80% of the auto travelers were also attracted to metro bus service due to reduction and travel cost and travel time.

Ridership is considered as a crucial component in transport industry. Travel analysis focuses on different types of riders mainly classified as regular users, potential users, captive users and non-users. Chang et al. (2007) classified passengers as non-users, option-users, users of a transportation service in Korea. Survey is conducted in which sociodemographic, travel characteristics and stated preference are asked by the respondents. Results revealed that the willingness-to pay of passengers is proportionate to the level of service of their primary travel mode. Le-Klähn et al. (2014) have examined the use and non-use of public transport in Munich, Germany. This study highlights the factors such as demographic characteristics, knowledge and experience that influence the use of public transport and also reveals the reasons of non-use of public transport. Questionnaire based survey has been conducted to access respondents' behavior in city Munich. Results showed that traffic reduction is one of the main reasons to use public transport and from the non-users perspective, frequency of public transport use at place of residence and ownership of driving license.

Rehman and Nahrin (2012) conducted survey in order to access users' opinion regarding metro bus service in Dhaka, Bangladesh. 76% of respondents mentioned the major reason of using metro bus service is its cheap fare than other transportation modes. Some of them considered it safe and fast. 47% of the respondents are found to be satisfied with physical conditions of metro bus service in Dhaka city.

Krizek and El-Geneidy (2006) have examined preferences and attitude of users and non-users of public transit in twin cities Minneapolis and St. Paul. Data on different variables i.e. origin, destination, riders' satisfaction and concern about the transit system, riders perception of safety and socio-demographics is collected to investigate the satisfaction level of users and non-users. Paper concluded that riders' satisfaction can be increased if technology of transit system tends to improve. Travel time is considered as a key factor in riders' satisfaction. Due to availability of smart cards, boarding time decreases and overall travel time decreases. Passengers show great satisfaction towards transit system.

Zhao et al. (2009) estimated the mode share of public transportation which includes bus, taxi and subway by using multinomial logit model reaches to a key point that normal bus users were insensitive to the travel time and travelers having higher level of income prefer to use taxis. Vedagiri and Arasan (2009) analyzed the mode shift behavior of car travelers to bus service by using binary logit model. They found that age, gender, purpose of making a trip and difference of time are major factors that affect the mode shift behavior of travelers and among those, mode shift for work purpose was quite large. In another study, Mark and Crispin (2005) estimated the travel mode choice of students for car and public transport, by using binary logit model and came to a conclusion that factors like travel time, number of cars owned and parking access show significant effects on mode shift behavior of students.

Based on the several other studies, the factors affecting traveler mode choice behavior in transportation sector may differ because of different trip purpose. The socioeconomic characteristics such as age, gender, income level, car ownership per adult, and trip characteristics such as travel cost, travel time, travel distance, level of service and frequency are considered as the significant factors that have a major impact of travelers' mode shift response.

The literature reveals that metro bus service has the potential to reduce carbon emissions which are emitted by vehicles due to model shift from private vehicles to public transport i.e. metro bus service. This service is also effective in road congestion issues and also considered as cost-effective due to the fact that it charges minimum amount of fare to its passengers. Passengers are satisfied with this service because of its certain benefits i.e. by using metro bus service fuel consumption of private vehicles is reduced and it also tends to save their travel time.

Chapter 3

DESCRIPTION OF STUDY AREA

This study is carried out for metro bus service located in Islamabad and its adjoining city, Rawalpindi. Islamabad, capital city of Pakistan is ranked as world's sixth most populous nation. It is considered as hub of political and economic activities. The population of Islamabad is 1.3 million, with the growth rate of 4 percent annually. Islamabad is linked with its neighboring city, Rawalpindi at its south end, which is another developing city with the population of 3.2 million. Together, both cities are considered as the third biggest urban amalgamation in Pakistan having 4.5million population (Pakistan Bureau of Statistics, 2015).

The main mode of mobility between the cities is only through private transport. There was no organized system of transportation in twin cities. Around 525,000 passengers are carried by over 210,000 vehicles on three major corridors of the cities. It is estimated that over 700,000 daily trips are taken within Islamabad, including 500,000 daily of trip to and from Rawalpindi alone (Asian Development Bank, 2012). Public transport in Islamabad contributed approximately 35% of the mode share of overall traffic, but this share is decreasing due to poor service (Asian Development Bank, 2012). During the last couple of years there has been an exceptional increment in vehicular activity which seriously effects urban ecosystem particularly because of increased rate atmospheric pollution and alterations in land use pattern.

In order to trap the serious issues in the city such as road congestion and increased rate of air pollution, Federal government in collaboration with Punjab Government launched bus rapid transit system on June 2015 in Rawalpindi-Islamabad region. It is 22.5 kilometres in length with 24 stations in the corridor starting from Pak. Secretariat and ends at Saddar, Rawalpindi[1]. The total number of stations in Rawalpindi is 10. (8.6km), while on the other hand, total number of stations in Islamabad part is 14. (13.9km). It carries 125,000 passengers on daily basis (Pakistan Metro Bus System, 2016). These BRT buses are separated from general traffic, in order to provide higher travel speed. They are designed to provide safe and comfortable environment to its passengers.

The basic emphasis of metro bus service is to cater the needs of low income communities residing in twin cities, especially women, elders and disadvantaged people. Its charges PKR 20 for each trip. This amount of fare is quite reasonable for all income groups, particularly, lower income groups.

Metro bus provides several benefits which include reduced motor vehicle accidents, savings in operating costs and travel time and will help make a superior urban condition by reducing congestion and pollution. Environmentally, the bus rapid transit system has a tendency to supplant more than 15 million km wagons, autos and motorcycle travel every year. It will positively affect climate change by decreasing CO2 discharge by more than 4,000 tons every year (Asian Development Bank, 2012).

[1] Nearest Famous Places from Metro Bus Stops are given in appendix 3.

Chapter 4

DATA AND METHODOLOGY

This study is composed of two sections. Section one provides a detailed analysis of mode shift behavior of public transport, own transport and taxi users after the launch of metro bus service in Islamabad- Rawalpindi region by using logistic regression model. Second part of the study provides the information related to carbon emission which are reduced due to metro bus. Certain calculation are made based on vehicle propulsion system and then these calculations will show the amount of carbon emissions which have reduced so far.

4.1. Logistic Regression Model:

Logistic regression also known as logit model analyzes the relationship between a dependent categorical variable and multiple independent variables (Park and Hyeounae, 2013). Logistic regression model is used in this study to examine the mode shift probabilities to metro bus service for public transport, own transport and taxi users for various purposes. The dependent variable i.e. purpose is in binary form and explanatory variables include gender, income, distance, travel cost and travel time. The general form of model is:

$$Y_i = \beta_\circ + \beta_1 X_i + \mu_i \quad \text{...................} \ (1)$$

Where Y_i is a dichotomous varible.

$$Y_i = \frac{1}{1+e^{-(\beta_\circ + \beta_1 X_i)}} \quad \text{................} \ (2)$$

$$Y_i = \frac{1}{1+e^{-Z_i}}$$

$$Y_i = \frac{e^z}{1+e^z} \text{ .... (3)}$$

Where $Y = \beta_\circ + \beta_i X_i + \mu_i$ .... (4)

In order to examine the mode shift behavior for public transport, own transport and taxi users after the implementation of metro bus service, logistic regression technique is used through Stata software. Explanatory variables used in this model are gender, family income, distance, travel cost and travel time for purpose. Purpose is divided into six categories i.e. job, education, shopping, hospital, friend and family visit and social activities. Purpose is taken as dependent variable. Hence, the econometric model is:

$$P_i = \beta_0 + \beta_1 gen + \beta_2 Inc + \beta_3 Dist + \beta_4 Ttime + \beta_5 Tcost + \mu_i \text{ ...... (5)}$$

Where:

Dependent Variable;

P_i = Purpose of visit, where i = 1 to 6.

i_1 = If purpose of using metro bus is job=1, else 0.

i_2 = If purpose of using metro bus is education=1, else 0.

i_3 = If purpose of metro bus is shopping=1, else 0.

i_4 = If purpose of using metro bus is hospital=1, else 0.

i_5 = If purpose of using metro bus is friend/family visit=1, else 0.

i_6 = If purpose of using metro bus is for social activities=1, else 0.

Independent Variables;

β_0 = Intercept

Gen = Gender of respondents

Inc= Family income of respondents

Dist = Distance from start point to destination (kilometers)

Ttravel= travel time.

Tcost= Travel cost.

μ= Error term.

This study analyzes 6 logit regression models for public transport, own transport and taxi users for 6 different purposes.

Model # 1:

Job purpose is taken as dependent variable for all three travel modes i.e. public transport, own transport and taxi. Job purpose is taken the form of dichotomous variable:

$$P_i = \begin{cases} 1 \; is \; for \; job \\ 0 \;\; Otherwise \end{cases}$$

1a. Metro- Public Transport Model:

This model examines the mode shift probability of public transport users for metro bus when the purpose is job. Explanatory variables are gender, income, distance, travel cost reduction and travel time reduction.

1b. Metro-Own Transport Model:

This model examines the mode shift probability of own transport users after the implementation of metro bus service when the purpose is job. Explanatory variables remain the same for all models.

1c. Metro-Taxi Model:

This model examines the mode shift probability of taxi users after the implementation of metro bus service when the purpose is job. Explanatory variables remain the same for all models.

Model # 2:

In model 2, travel modes and explanatory variables remain same and education is taken as purpose.

$$P_i = \begin{cases} 1 \ is \ for \ education \\ 0 \ \ Otherwise \end{cases}$$

Education purpose is regressed separately for each travel mode.

2a. Metro- Public Transport Model:

This model examines the mode shift probability of public transport users for metro bus when the purpose is education. Explanatory variables are gender, income, distance, travel cost reduction and travel time reduction.

2b. Metro-Own Transport Model:

This model examines the mode shift probability of own transport users after the implementation of metro bus service when the purpose is education. Explanatory variables remain the same for all models.

2c. Metro-Taxi Model:

This model examines the mode shift probability of taxi users after the implementation of metro bus service when the purpose is education. Explanatory variables remain the same for all models.

Model # 3:

In this model shopping purpose is taken as dependent variable for all three travel modes i.e. public transport, own transport and taxi. Shopping purpose is taken the form of dichotomous variable:

$$P_i = \begin{cases} 1 \ is \ for \ shopping \\ 0 \ \ Otherwise \end{cases}$$

3a. Metro- Public Transport Model:

This model examines the mode shift probability of public transport users for metro bus when the purpose is shopping. Explanatory variables are gender, income, distance, travel cost reduction and travel time reduction.

3b. Metro-Own Transport Model:

This model examines the mode shift probability of own transport users after the implementation of metro bus service when the purpose is shopping. Explanatory variables remain the same for all models.

3c. Metro-Taxi Model:

This model examines the mode shift probability of taxi users after the implementation of metro bus service when the purpose is shopping. Explanatory variables remain the same for all models.

Model # 4:

In model 4, travel modes and explanatory variables remain same and visit to hospital is taken as dependent variable.

$$P_i = \begin{cases} 1 \ is\ for\ hospital \\ 0 \ \ Otherwise \end{cases}$$

4a. Metro- Public Transport Model:

In this model, hospital purpose is regressed on gender, income, distance, travel cost reduction and travel time reduction for public transport. This further estimates the shift probabilities of public users for metro bus.

4b. Metro-Own Transport Model:

This model examines the mode shift probability of own transport users after the implementation of metro bus service when the purpose is visit to hospital. Explanatory variables remain the same for all models.

4c. Metro-Taxi Model:

This model examines the mode shift probability of taxi users after the implementation of metro bus service for hospital purpose. Explanatory variables remain the same for all models.

Model # 5:

In this model shopping purpose is taken as dependent variable for all three travel modes i.e. public transport, own transport and taxi. Friend/family visit purpose is taken the form of dichotomous variable:

$$P_i = \begin{cases} 1 \; is \; for \; friend/family \; visit \\ 0 \; Otherwise \end{cases}$$

5a. Metro- Public Transport Model:

This model examines the mode shift probability of public transport after implementation of metro bus for friend/ family visit. Explanatory variables are gender, income, distance, travel cost reduction and travel time reduction.

5b. Metro-Own Transport Model:

In this model, friend/family visit purpose is regressed on gender, income, distance, travel cost reduction and travel time reduction for public transport. This further estimates the shift probabilities of public users for metro bus.

5c. Metro-Taxi Model:

This model examines the mode shift probability of taxi users after the implementation of metro bus service when the purpose is friend/family visit. Explanatory variables remain the same for all models.

Model # 6:

In model 6, travel modes and explanatory variables remain same and social activities purpose is taken as dependent variable.

$$P_i = \begin{cases} 1 \ is\ for\ social\ activities \\ 0 \ \ Otherwise \end{cases}$$

Social activity purpose is regressed separately for each travel mode.

6a. Metro- Public Transport Model:

This model examines the mode shift probability of public transport users for metro bus when the purpose is social activities. Explanatory variables are gender, income, distance, travel cost reduction and travel time reduction.

6b. Metro-Own Transport Model:

This model examines the mode shift probability of own transport users after the implementation of metro bus service when the purpose is social activities. Explanatory variables remain the same for all models.

6c. Metro-Taxi Model:

This model examines the mode shift probability of taxi users after the implementation of metro bus service when the purpose is social activities. Explanatory variables remain the same for all models.

4.2. Sample Design:

This study focuses on Rawalpindi-Islamabad bus rapid transit and aims to examine the mode shift behavior of passengers from their previous mode such as public transport, own transport and taxi after the introduction of metro bus service in the city. A primary survey is conducted in order to analyze the commuters' perception regarding the use of metro bus service. The data is collected from commuters by using questionnaire based surveys in the months of February, March and April, 2017 from various stations of metro bus. Data is collected from different stations of metro route during weekdays, weekends, and peak hours and off- peak hours. Time of visit to stations during peak hours was 7:00 am to 10:00 am in morning and 3:30 pm to 6:30 pm in evening and survey conducted during operation hours was 11:00am to 2:00 pm and 7:00pm to 8:00 pm (off peak hours). The sample selection according to formula with 5% error term from 125,000 daily passengers of metro bus is 360, but in order to avoid any incomplete information, a total of around 445 samples were finalized from the study area.

4.3. Questionnaire:

Questionnaire[2] is divided into two heads i.e. socio-economic characteristics and travel characteristics of travelers as shown in table 4.1. Socio-economic characteristics such as gender, age, income level, occupation, car ownership; travel characteristics like travel cost, travel time, travel distance. These characteristics are considered as the primary factors that could influence mode shift behavior according to past studies. Respondents are also asked about the trip purposes and demographics of metro bus and also frequency of metro usage. Savings in travel time and travel cost are estimated and then amount of carbon emissions reduced is calculated.

Table 4.1: Survey Components

Classification	Components
Socio- demographics	Gender, age, income, education, occupation, Car ownership, etc.
Travel characteristics	Trip purpose, travel cost, travel time, travel mode, etc.

4.4. Variables and Description:

Following variables are used in the logistic regression model:

- **Gender:**

  This variable is considered as dummy variable for gender between male and female group. Where male =1, else, 0.

[2] Questionnaire is given in appendix 4.

- **Income:**

Income of respondents is included in model to estimate the income effect on different mode choices. It is taken as a continuous variable.

- **Education:**

Education variable includes the education level of respondents. It varies from illiterate to 20 years of education. Codes are assigned to each education year. Code 1 is for 0 year, code 2 is for 5 years, code 3 is for 8 years, code 4 is for 10 years, code 5 is for 12 years, code 6 is for 14years, code 7 is for 16 years and code 8 is assigned for 20 years of education.

- **Occupation:**

Occupation includes the occupation of respondents. Codes are assigned for each occupation. Code 1 is assigned to student, code 2 is for govt. employee, code 3 is for emp.in private sector, code 4 is for manual worker, code 5 is for business/trade, code 6 is for household woman, code 7 is for banker, code 8 is for doctor, code 9 is for nurse and code 10 is assigned to teacher.

- **Distance:**

This variable is defined as the distance between start of journey and destination of respondents. It is also taken as continuous variable.

- **Purpose:**

Purpose means the reason for using metro bus. It is taken as dependent variable in the model. There are 6 purposes i.e. job, education, shopping, hospital, friend/family visit and social activities. Each purpose is taken separately for different travel modes.

- **Travel Cost:**

Total amount of travel cost which is borne by the passengers is taken as a major variable in model.

- **Travel time:**

Total amount of time spent during travel by passengers is also taken as a major variable in model.

According to previous studies, (Vedagiri and Arasan, 2009; Wang and Gan, 2010), travel cost and travel time provides better explanation in models.

4.5. Carbon Emission Calculations:

In order to calculate the carbon emissions, reduced due to metro bus in last 2 years, this study tends to find out the number of public vans which were replaced due to metro bus, then according to their propulsion systems, amount of carbon emissions emitted by these vans are calculated and lastly it is compared with the carbon emission of metro bus and the difference is taken to show that how much carbon emissions are reduced in the previous couple of years.

Chapter 5

RESULTS AND DISCUSSION

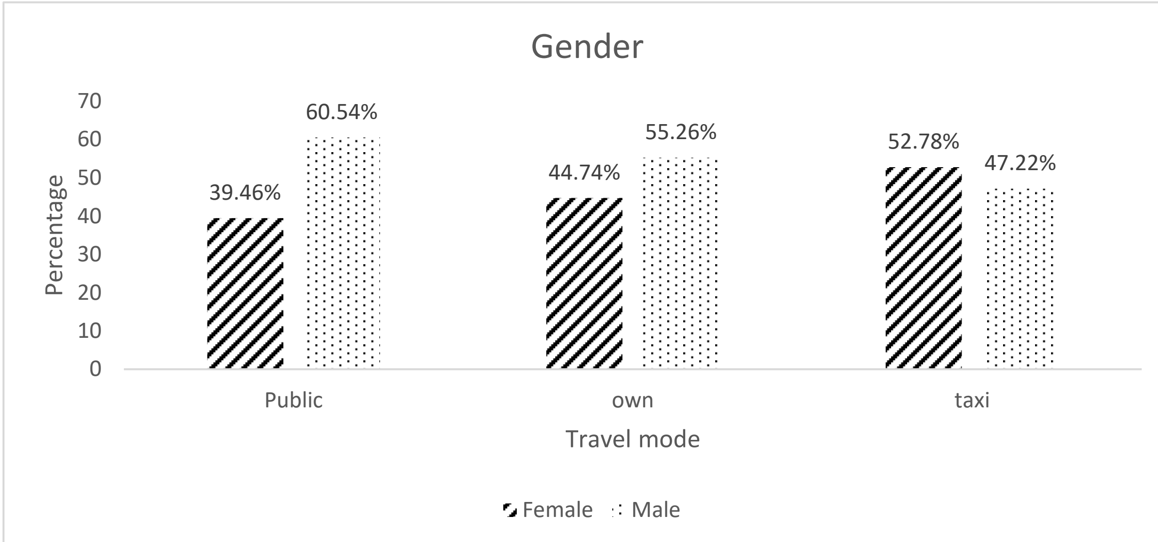
5.1. Descriptive Statistics:

This chapter discusses in detail the demographics of metro bus commuters. The respondents who were using three modes of transport (public transport, own transport and taxi) before metro bus is given in figure 5.1.

- For public transport travelers, out of 223 respondents, male respondents accounted for around 60.54% and female respondents were 39.46%.
- In case of own transport users, among 114 respondents, 55.26% respondents were male and 44.74% respondents were female.
- Out of 108 taxi users, 47.2% were male respondents and 52.78% were female respondents.

It is clear and evident from ground realities, that, males prefer public transport as compared to females, being low in fare whereas, females prefer taxi because of safe and comfortable ride.

Figure 5.1: Gender Based Travel Mode of Respondents.



5.1.1. Summary Statics of Socio-Economic Variables:

Table 5.1.1: Summary Statistics of Socio-Economic Variables

Variables	Min	Max	Mean	S.D
Age	15	56	24.957	7.30
Income	5000	300000	58871.922	29393.15
Education	1	8	5.623	1.36
Occupation	1	10	2.623	2.70

Table 5.1.1 shows the descriptive statistics of socio-economic variables. Out of 445 total sample, 249 respondents are males and 196 are females. Age of respondents ranges from 15 years to 56years. Mean age of respondents is 25 years. Average monthly income of respondents is PKR 59485. Monthly income ranges from PKR 5000 to PKR 300,000. Education level of respondents varies from illiterate to 20 years of education. Mean education level is 12 and 14 years of education.40.19% of the respondents have 14 years

of education. Both 12 years and 16 years of education constitutes of around 61.6% of total sample size. Most of the travelers are students (62.71%), government employees (6.49%) and private sector employees (9.83%).

5.1.2. Occupation of Respondents:

Listed below are the occupations of respondents who used to travel by public transport, own transport and taxi before the launch of metro bus service in the city. Table 5.1.2 shows the occupation based mode shift behavior of the respondents.

Table 5.1.2: Occupation Information of Survey data (%):

Alternative mode		Public Transport	Own Transport	Taxi
Occupation	Student	56.50	66.67	75
	Govt. Employee	10.31	7.89	2.78
	Emp.In Private Sector	9.42	20.18	8.33
	Manual Worker	5.83	-	-
	Business/Trade	-	1.75	-
	Household Woman	3.59	-	10.19
	Banker	6.28	-	1.85
	Doctor	3.59	3.51	1.85
	Nurse	1.79	-	-
	Teacher	2.69	-	-
Observations		223	114	108

Table 5.1.2 shows the occupation of respondents who used public transport, own transport and taxi before the introduction of metro bus service in Islamabad- Rawalpindi region. Detail is provided as follows:

- Out of 223 observations of public transport users, 56% students use public transport before metro bus or in other words, 56% students shift their mode from public transport to metro bus, around 66% shifted from their own transport and 75% shifted from taxi towards metro bus service.

- For government employees, 10.31% shifted from public transport, 7.89% from own transport and 2.78% from taxi towards metro bus service.
- Similarly for respondents who are employees in private sector, around 9.42% shifted their travel mode from public transport to metro, 20.18% shifted from own transport while 8.33% shifted from taxi towards metro bus service.
- Around 5.83% manual workers stated that they traveled in public transport before metro bus and now they are using metro bus service.
- Around 1.75% businessmen/traders shifted their travel mode from own transport to metro bus.
- 3.59% and 10.19% household women who shifted from public transport and taxi respectively towards metro bus.
- For bankers, who shifted from public transport to metro bus are 6.28% and 1.85% shifted from taxi to metro bus.
- The percentage of doctors who shifted their travel mode from public transport to metro is 3.59%, 3.51% from own transport and 1.85% from taxi to metro bus.
- The percentage of nurses who shift their travel mode from public transport to metro bus is 1.79%.
- The mode shift of teachers from public transport to metro bus is 2.69%.

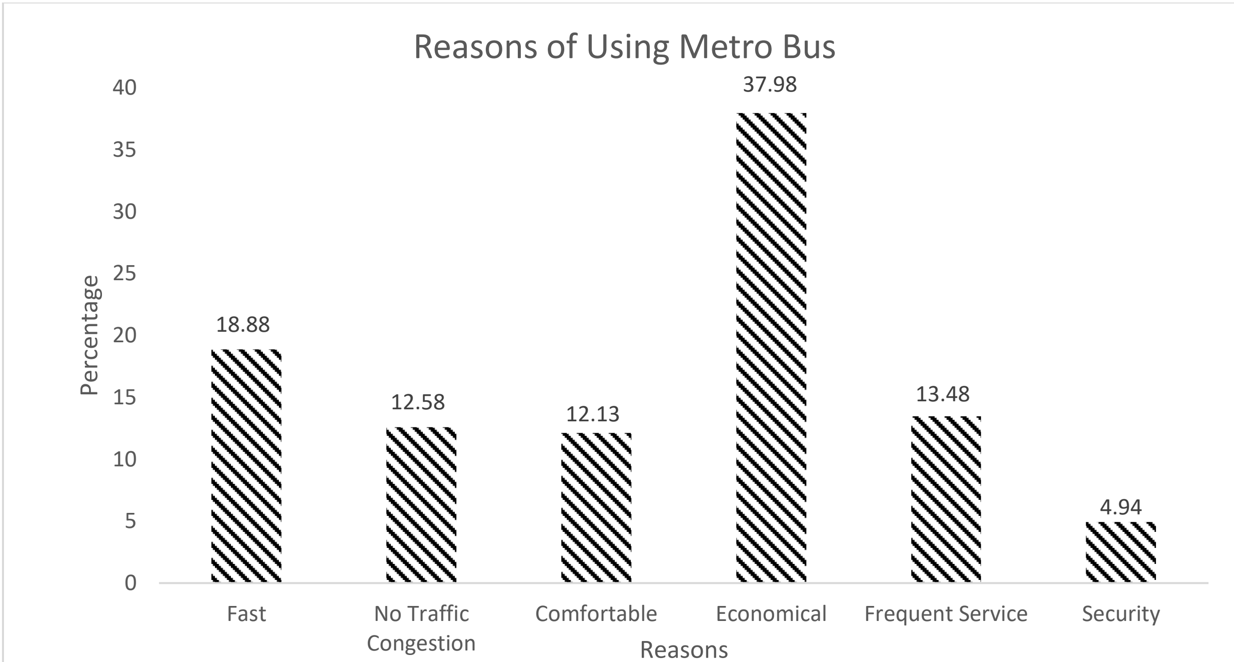
5.1.3. Gender Based Trip Purpose of Metro Bus Users:

Table 5.1.3: Trip Purpose of Metro Bus Users (%):

Gender	Job	Education	Shopping	Hospital	Friend	Social	Total
Female	12.58	11.46	7.64	7.42	1.35	3.60	44.04
Male	12.13	11.69	8.09	3.15	12.58	8.31	55.96
Total	24.72	23.15	15.73	10.56	13.93	11.91	100

Table 5.1.3 summarizes the gender based trip purposes of metro bus users. It shows that 47% trips are for job and education made by both males and females. For shopping purpose, 7.64% females and 8.09% males use metro bus service. Around 3.15% males and 7.42% females reported that they use metro bus service for health related purpose i.e. to visit hospital. The ratio for female is doubled as compared to males for hospital, means that females alone visit hospitals for their own treatment and also for their children. For about 12.58% males and 1.35% females reported that they use metro bus service to visit friends and family while 8.31% males and 3.60% females responded that they use metro bus service for social activities.

Figure 5.2: Reasons of Using Metro Bus



Reasons behind the use of metro bus system are shown in figure 5.3. Around 18.88% of the travelers stated that they use metro bus because of its fast speed. Clog free travel accounts for about 12.58% of the reasons presented for using metro bus service. Comfortable travel accounts for 12.13%. Economical/cheap ride accounts for around 37.98% of the reasons referred for using metro bus service. Frequent service and safe ride are also considered as significant features for using metro bus service and accounts for 13.48% and 4.94% respectively. Metro bus riders are pulled into the framework on account of its speed, economical advantage, congestion free travel and comfortable and frequent service.

5.1.4. Frequency of Metro Bus Use:

Table5.1.4: Frequency of Metro Bus Use.

Frequency	# of response	Percent	Cum.
once in month	84	18.88	18.88
daily	187	42.02	42.02
weekends	134	30.11	91.01
2times a week	25	5.62	96.63
4times a week	15	3.37	100.00
Total	445	100.00	

Table 5.1.4 reflects the frequency of metro bus use. Around 42.02% of the surveyed passengers use metro bus service on daily routine and 30.11% use it only on weekends. The percentage of passengers who ride metro bus once in a month is 18.88%. Passengers who travel 2 times a week and 4 times a week together constitutes for about 8.99%.

5.1.5. Travel Cost and Travel Time of Different Mode Travelers:

Table5.1.5: Travel Cost and Time.

Alternative mode		Public Transport	Own Transport	Taxi
Travel Cost(PKR)	Mean	1435.47	2753.5	1233.33
	S.D	(1181.3)	(2744.66)	(794.84)
	Min	50	200	300
	Max	5000	10000	4000
Travel Time(Mnts.)	Mean	49.8	46.44	57.87
	S.D	(22)	(14.28)	(19.84)
	Min	20	20	25
	Max	120	90	90

Table 5.1.5 exhibits the summary statistics of travelers' trip cost per month and travel time in terms of mean, minimum, maximum and standard deviation (S.D). It reveals that

public transport users spent an average of PKR 1435 on travel, where the minimum cost is PKR 50 and maximum cost borne by public transport users is PKR 5000. Similarly, in case of own transport users, a mean of PKR 2753 is spent on their travel and for taxi users, a mean of PKR 1233 is spent on travel per month.

In terms of travel time, around 50 minutes are consumed by public transport users for their travel purpose. An average of 46 minutes are consumed by own transport users and for taxi users, an average of 58 minutes are consumed for travel purpose.

5.1.6. Savings and Benefits from Metro Bus Service:

Table5.1.6: Travel Cost and Time Reduction.

Alternative mode		Public Transport	Own Transport	Taxi
Travel Cost Reduction(PKR)	Mean	801.21	2268.98	1091.29
	S.D	(773.38)	(2473.06)	(671.70)
	Min	10	100	260
	Max	3800	8800	2960
Travel Time Reduction (Mints.)	Mean	23.78	20.21	25.23
	S.D	(12.04)	(5.65)	(9.72)
	Min	10	10	15
	Max	60	45	50

It is obvious from table 5.6, Metro Bus service has reduced an average of 801 PKR monthly, for those travelers, who use public transport before the launch of metro bus service. Own transport users have saved on average 2269PKR monthly, by shifting their travel mode towards metro bus. Similarly taxi users also saved 1091PKR on monthly basis by converting travel mode to metro bus.

In terms of travel time reduction, public transport users stated that an average of 24 minutes are saved by using metro bus, whereas for own transport users, an average of 20 minutes are reduced. Similarly an average of 25 minutes are saved for each trip of taxi users. The reason is metro bus has a separate route, while there is a lot of traffic on other roads, which is the major cause of traffic congestion, due to which a lot of time is consumed on roads.

5.2. Interpretation of Models:

The following tables discuss in detail the results obtained from the econometric model explained in previous chapter. As mentioned in the objectives, this study aims to analyze the mode shift behavior of public transport, own transport and taxi users after the implementation of metro bus service. Tables 5.1, 5.2, 5.3, 5.4, 5.5 and 5.6 shows the logistic regression results for job, education, shopping, hospital, friend/family visit and social activities purposes respectively for all transport modes. Explanatory variables of gender, income, distance, travel cost and travel time are also included.

5.2.1. Model-1: Logistic Regression Model for Job Purpose:

Table 5.2.1:Logistic regression Model for Job Purpose

	Model 1a			Model 1b			Model 1c		
Variables	**β**	**Odds Ratio**	**%**	**β**	**Odds Ratio**	**%**	**β**	**Odds Ratio**	**%**
Gender	0.141 (0.712)	1.152	15.3	-2.427 (0.001)	0.088	-91.2	-0.492 (0.04)	0.611	-38.9
Income	0.000 (0.019)	0.999	0.000	0.000 (0.015)	1.000	0.000	0.000 (0.938)	1	0.000
Distance	0.102 (0.002)	1.108	10.8	0.323 (0.000)	1.382	38.2	0.111 (0.000)	1.118	11.8
Travel Cost	0.001 (0.000)	1.001	0.1	0.001 (0.01)	1.004	0.1	0.005 (0.000)	1.0004	0.1
Travel Time	0.048 (0.002)	1.049	4.9	0.097 (0.019)	0.907	9.3	0.034 (0.003)	1.035	3.6
Constant	-3.358 (0.000)	0.034	.	-3.409 (0.02)	0.033	.	-3.272 (0.000)	0.037	
Observations		223			114			108	
Pseudo R^2		0.2631			0.4805			0.2444	

Table shows the logistic regression results estimated from equation 5 for model 1 i.e. when the dependent variable is job purpose. This table exhibits the mode shift behavior of public transport, own transport and taxi users after the introduction of metro bus for job purpose.

In model 1a i.e. metro- public transport model, the logistic regression coefficient of gender is 0.141, which shows that males have15.3% greater odds to shift towards metro bus service. The probability of this shift towards metro is 1.152 units. Income has no impact on mode shift behavior, means when income increases by 1%, then there is no change in mode shift from public transport to metro bus. The regression estimate of distance is 0.102, which implies that as distance increases, likelihood of public transport users to shift towards metro bus increases by 1.108 units. Further it indicates that each additional kilometer increase in distance increases the log odds of shifting towards metro bus by 10.8%. Trip cost also shows significant results for mode shift towards metro bus service. The regression coefficient is positive and significant at 0.01 significance level, indicating that trip cost increases the probability to shift to metro bus service by 1.001 units. As travel cost of public transport increases, the likelihood to travel by metro bus service increases by 0.1%. Lower travel cost of metro attracts the lower and middle income groups to shift their travel mode from public transport to metro bus. Notably, the regression coefficient of travel time is positive and significant, indicating that travel time increases the probability of travelers to shift to metro bus by 1.049 units. Travel time plays a vital role for those who travel for job purpose. As travel time of public transport increases, the likelihood to travel by metro bus service increases by 4.9%.

Model 1b i.e. metro- own transport model, shows the mode shift behavior of own transport users after the introduction of metro bus. The logistic regression coefficient of gender is -2.427, which shows that males are less willing to shift towards metro bus and continue using their own transport. In terms of percentage, males have 91.2% greater odds of using their previous mode of travel as compared to females. Income has no impact on mode shift behavior for job purpose. The regression estimate of distance is 0.323, which implies that as distance increases, likelihood of own transport users to shift towards metro bus increases by 1.382 units. Further it indicates that each additional kilometer increase in distance increases the log odds of shifting towards metro bus by 38.2%. Trip cost also shows significant results for mode shift towards metro bus service. The regression coefficient is positive and significant at 0.01 significance level, indicating that trip cost increases the probability to shift to metro bus service by 1.004

units. As travel cost by own transport increases, the likelihood to travel by metro bus service increases by 0.1%. Lower travel cost of metro attracts the lower and middle income groups to shift their travel mode from public transport to metro bus. The logistic regression coefficient of travel time is positive and significant, indicating that travel time increases the probability of travelers to shift to metro bus by 0.907 units. Travel time plays a vital role for those who travel for job purpose. As travel time increases, the likelihood to travel by metro bus service increases by 9.3%.

Model 1c i.e. metro- taxi model also shows logistic regression results. All the explanatory variables are statistically significant except income which is insignificant variable. The logistic estimates for gender is -0.492, which indicates that male travelers are less willing to travel by metro as compared to female travelers. It further exhibits that males have 38.9% greater odds of using taxi as compared to metro bus. Like above two models, income has no impact on taxi travelers. The logistic regression coefficient of distance is 0.111. It is positive and statistically significant. Odds ratio of distance variable explains that 1 kilometer increase in distance leads to 1.118 units increase in the likelihood to shift to metro bus. The percentage of this shift towards metro is 11.8%. The logistic estimate of travel cost is 0.005. This variable is statistically significant at 0.000 significance level. In terms of percentage, as travel cost of taxi increases, the log odds for mode shift towards metro bus increases by 0.1%. Likewise, travel time is also statistically significant at 0.003 significance level. The logit coefficient of this variable is 0.034. As travel time increases, the likelihood to shift towards metro from taxi mode increases by 3.6%.

The pseudo R square for metro-public is 0.2631. It indicates that 26% variation in dependent variable is explained by the explanatory variables whereas, the pseudo R square for metro-own is 0.4805, shows 48% variation in model is explained by the explanatory variables. On the other hand, the pseudo R square for metro-taxi model is 0.2444 shows 24% variation in model is explained by explanatory variables.

In terms of significance level, distance, travel time and trip cost are considered to be most influential variables in selection of metro bus service for job purpose.

5.2.2. Model-2: Logistic Regression Model Education Purpose:

Table 5.2.2: Logistic Regression Model for Education Purpose.

	Model 2a			Model 2b			Model 2c		
Variables	**β**	**odds Ratio**	**%**	**β**	**Odds Ratio**	**%**	**β**	**Odds Ratio**	**%**
Gender	-1.31 (0.001)	0.270	-72.9	-0.197 (0.70)	0.820	-17.9	-0.314 (0.58)	0.729	-27.0
Income	0.000 (0.03)	1.000	0.0	0.000 (0.001)	0.999	0.00	-0.00 (0.52)	0.999	-0.00
Distance	0.174 (0.000)	0.840	15.9	-0.032 (0.40)	0.968	-3.2	-0.045 (0.1)	0.956	-4.4
Travel Cost	0.004 (0.07)	1.001	0.1	0.002 (0.1)	0.98	0.2	0.005 (0.02)	1.0004	0.1
Travel Time	0.076 (0.001)	0.926	7.3	0.038 (0.03)	1.04	3.9	0.025 (0.04)	1.025	2.5
Constant	1.486 (0.03)	0.034	.	1.93 (0.11)	6.941	.	0.116 (0.92)	1.123	
Observations		223		114			108		
Pseudo R^2		0.2868		0.1947			0.2660		

Table 5.2.2 exhibits the logistic regression results for education purpose.

In model 2a i.e. metro- public transport model, the logistic regression coefficient of gender is -1.31, which shows that males have 72.9% greater odds to travel by their existing modes and they are not willing to shift towards metro bus. Income has no impact on mode shift behavior. The logit estimate of distance is 0.174, which implies that as distance increases, likelihood of public transport users to shift towards metro bus increases by 0.840 units. Further it indicates that each additional kilometer increase in distance increases the log odds of shifting towards metro bus by 15.9%. Trip cost also shows significant results for mode shift towards metro bus service for education purpose. The regression coefficient is positive and significant at 0.1 significance level, indicating that trip cost increases the probability to shift to metro bus service by 1.001 units. As travel cost increases, the likelihood to travel by metro bus service increases by 0.1%. Lower travel cost of metro attracts the lower and middle income groups to shift their travel mode from public transport to metro bus. The regression coefficient of travel time is positive and significant, indicating that travel time increases the probability of travelers to shift to metro bus by 0.926 units. As travel time increases, the likelihood to travel by metro bus service increases by 7.3%.

Model 2b i.e. metro- own transport model shows the mode shift behavior of own transport users after the introduction of metro bus. The logistic regression coefficient of gender is -0.197, which shows that males are less willing to shift towards metro bus and continue using their own transport. In terms of percentage, males have 17.9% greater odds of using their previous mode of travel as compared to females. Again, Income has no impact on mode shift behavior for education purpose. The regression estimate of distance is -0.032, which implies that as distance increases, likelihood of own transport users to shift towards metro bus decreases by 0.968 units. The coefficient of distance is negative for own transport mode, which means that own transport travelers are not willing to shift to metro mode and continue their existing mode. Further it indicates that each additional kilometer increase in distance decreases the log odds of shifting towards metro bus by 3.2%. Trip cost also shows significant results for mode shift towards metro bus service. The regression coefficient is positive and significant at 0.1 significance level, indicating that trip cost increases the probability to shift to metro bus service by 0.98 units. As travel cost increases, the likelihood to travel by metro bus service increases by 0.2%. Lower travel cost of metro i.e. 20PKR for a single trip attracts the lower and middle income groups to shift their travel mode from public transport to metro bus. The logistic regression coefficient of travel time is positive and significant, indicating that travel time increases the probability of travelers to shift to metro bus by 1.04 units. Travel time plays a vital role for those who travel for job purpose. As travel time increases, the likelihood to travel by metro bus service increases by 3.9%.

Model 2c shows the logistic regression results for metro-taxi mode. All the explanatory variables are statistically significant except gender and income which are insignificant variables. The logistic estimates for gender is -0.314, which indicates that male travelers are less willing to travel by metro as compared to female travelers. It further exhibits that males have 27% greater odds of using taxi as compared to metro bus. Like above two models, income has no impact on taxi travelers. The logistic regression coefficient of distance is- 0.045. It is negative and statistically significant. Odds ratio of distance variable explains that 1 kilometer increase in distance leads to 0.956 units decrease in the likelihood to shift to metro bus. It further indicates that the log odds of shifting to metro bus decrease by 4.4%, if distance increases by 1 kilometer. The logistic estimate of travel cost is 0.005. This variable is statistically significant at 0.000 significance level. In terms of percentage, as travel cost increases, the log odds for mode shift towards metro bus increases by 0.1%. Travel time is also statistically significant at 0.04. The logit coefficient of this variable is 0.025. As travel time increases, the likelihood to shift towards metro from taxi mode increases by 2.5%.

The pseudo R square for metro-public is 0.2868, means that 28.6% variation in model is explained by the explanatory variables while the pseudo R square for metro-own transport model is 0.1947, shows 19% variation is explained by explanatory variables in the model. The pseudo R square for metro-taxi model is 0.2660, means that 26.6% variation in the model is explained by explanatory variables.

In terms of significance level, distance, travel time and trip cost are considered to be most influential variables in selection of metro bus service for education purpose.

5.2.3. Model-3: Logistic Regression Model for Shopping Purpose:

Table 5.2.3: Logistic Regression Model for Shopping Purpose.

	Model 3a			**Model 3b**			**Model 3c**		
Variables	**β**	**odds Ratio**	**%**	**β**	**Odds Ratio**	**%**	**β**	**Odds Ratio**	**%**
Gender	-0.136 (0.643)	0.872	-12.8	-0.298 (0.215)	0.742	-25.8	-1.582 (0.030)	0.204	-79.5
Income	-0.000 (0.760)	0.999	0.0	-0.000 (0.301)	0.999	-0.00	-0.000 (0.060)	0.999	-0.00
Distance	0.041 (0.01)	0.959	4.0	0.052 (0.020)	0.949	5.1	0.095 (0.147)	0.909	9.1
Travel Cost	0.003 (0.08)	0.999	0.1	0.005 (0.002)	0.999	0.1	0.002 (0.06)	0.999	0.1
Travel Time	0.01 (0.05)	1.001	0.2	0.010 (0.03)	0.989	1.0	0.030 (0.08)	0.969	3.0
Constant	0.407 (0.41)	1.502	.	1.080 (0.014)	2.94	.	5.175 (0.01)	176.89	
Observations		223			114			108	
Pseudo R^2		0.286			0.152			0.217	

Table 5.2.3 exhibits the logistic regression results for three travel modes, when the purpose is shopping as already mentioned in model 3 in chapter 4.

In model 3a, i.e. metro- public mode for shopping purpose, the logit estimate of gender is -0.136, shows that male travelers are less willing to shift their mode of travel towards metro bus as compared to females. The probability of male travelers to shift to metro decreases by 12.8%. Income has no effect on shift mode, but here it shows inverse association between income and shift towards metro bus when the purpose of travelers is shopping. It means that with an increase in income, the probability to shift to metro bus decreases. The regression coefficient of distance is 0.041, which shows a positive relation between distance and mode shift behavior. Odds ratio of distance explains that one kilometer increase in distance leads to 0.959 units increase in the mode shift behavior of public travelers towards metro bus, whereas in terms of percentage, with additional kilometer increase in distance, increases the log odds to shift towards metro bus increases by 4%. The logit estimate of travel cost in metro-public mode is 0.003 and it is statistically significant at 0.1 significance level. Reduced cost of metro attracts the passengers of other modes by 0.1% for shopping purpose, whereas the odds ratio of this variable indicates that with 1PKR increase in travel cost leads to 0.999 units increase in mode shift behavior towards metro bus service. Correspondingly, travel time has the logit estimate of 0.01 and is significant at 0.05 significance level. Odds ratio of this variable indicates that each additional minute of travel time spent on public transport leads to the increased likelihood to travel by metro by 1.001 units. The mode shift due to travel time towards metro is 0.2%.

Turning to model 3b, where metro-own transport model is estimated for shopping purpose. In explaining gender variable, the logit estimate of this variable is -0.298, which indicates that male travelers are less willing to shift their travel mode to metro bus for shopping purpose as compared to female travelers. In terms of percentage, there is 25.8% decline in mode shift behavior of male travelers. In this case, income again has no impact on mode shift behavior, but its coefficient reveals a negative association with mode shift. It means that as income of travelers tends to increase, the probability to shift towards metro bus service decreases and individuals continue to travel by own transport. It is quite obvious from this result that high income individuals are not attracted by the low fare of metro bus service. Distance has the logit coefficient of 0.052, which shows a positive association with mode shift to metro for own transport users. Odds ratio of distance interprets that one kilometer increase in distance leads to 0.949 units increase in the likelihood to shift towards metro bus service. Furthermore, the log odds to shift to metro increases by 5.1%. The logistic regression coefficient of travel cost variable is 0.005 and it is statistically significant at 0.01 significance level. Moreover, it illustrates that low cost of metro attracts the own transport travelers by 0.1% for shopping purpose, whereas the odds ratio of this variable indicates that with 1PKR increase in cost reduction leads to 0.999 units increase in mode shift behavior towards metro bus service. Likewise, travel time has the logit estimate of 0.01 and is significant at 0.05 significance level. Odds ratio of this variable indicates that each additional minute spent on travel time for own transport leads to the increased likelihood to travel by metro by 0.989 units. The mode shift due to travel time towards metro is 1.0%.

As for model 3c i.e. metro-taxi model, the logistic regression results of this model are mentioned here for shopping purpose. Starting from gender variable, the logit estimate of gender is -1.582, shows that male travelers are less willing to change their travel mode from taxi to metro bus as compared to female travelers. The probability of male travelers to shift to metro decreases by 12.8%, while the P-value shows that this variable is significant at 0.05 significance level. Again income has no impact on mode shift behavior, but its coefficient is negative, which interprets that as income tends to rise, travelers use taxi for shopping purpose and not preferring metro bus service. Next, the logit estimate of distance variable is 0.095. It shows a positive association with mode shift to metro bus. Odds ratio interprets that with each additional kilometer increase in distance, increases the mode shift behavior towards metro bus by 0.909 units. It further explains that if distance increases by one kilometer, then the log odds for shifting towards metro mode from taxi mode increases by 9.1%. The logistic estimate of travel cost is 0.002. This variable is statistically significant at 0.1 significance level. In terms of percentage, as travel increases, the log odds for mode shift towards metro bus increases by 0.1%. Travel time is also statistically significant at 0.1 significance level. The logit coefficient of this variable is 0.969. As in travel time increases, the likelihood to shift towards metro from taxi mode increases by 3%.

The pseudo R square for metro-public is 0.2868 and it shows that 28.6% variation in the model is explained by t explanatory variables, while The pseudo R square for metro-own transport model is 0.152, indicates that explanatory variables in the mode explain 15% variation in the model. On the other hand, the pseudo R square for metro-taxi model is 0.2170, shows around 21.7% variation in model due to explanatory variables.

5.2.4. Model 4- Logistic Regression Model for Hospital Purpose:

Table 5.2.4: Logistic Regression Model for Hospital purpose.

	Model 4a			Model 4b			Model 4c		
Variables	**β**	**odds Ratio**	**%**	**β**	**Odds Ratio**	**%**	**β**	**Odds Ratio**	**%**
Gender	-0.522 (0.07)	0.592	-40.7	-0.998 (0.000)	0.368	-63.2	-1.582 (0.030)	0.204	-79.5
Income	0.000 (0.66)	1.000	0.0	0.000 (0.650)	1.000	0.00	0.0002 (0.250)	1.0002	0.000
Distance	0.045 (0.09)	1.046	4.6	0.024 (0.290)	1.025	2.5	-0.019 (0.842)	0.980	-1.9
Travel Cost	0.0013 (0.16)	0.998	0.1	-0.0007 (0.000)	0.999	-0.1	-0.004 (0.163)	0.995	-0.5
Travel Time	0.008 (0.49)	0.991	0.8	-0.0173 (0.152)	0.982	-1.7	-0.072 (0.441)	0.930	-7.0
Constant	-0.320 (0.51)	0.725	.	0.478 (0.295)	1.612	.	-8.824 (0.293)	0.0001	
Observations		223			114		108		
Pseudo R^2		0.0214			0.0741		0.3115		

Table 5.2.4 shows the logistic regression results estimated for model 4 i.e. when the dependent variable is visit to hospital purpose. This table exhibits the mode shift behavior of public transport, own transport and taxi users after the introduction of metro bus for health related purpose

In model 4a i.e. metro- public transport model, the logistic regression coefficient of gender is -0.522, which shows that the likelihood of male travelers to shift towards metro mode decreases by 0.592 units. The log odds of male travelers to shift towards metro mode for hospital purpose decreases by 40.7% as compared to females. Income has no impact on mode shift behavior. The regression estimate of distance is 0.045, which implies that as distance increases, likelihood of public transport users to shift towards metro bus increases by 1.046 units. Furthermore, it indicates that each additional kilometer increase in distance increases the log odds of shifting towards metro bus by 4.6%. Trip cost also shows significant results for mode shift towards metro bus service. The regression coefficient is positive and significant at 0.1 significance level, indicating that trip cost increases the probability to shift to metro bus service by 0.998 units. As travel cost for own transport increases, the likelihood to travel by metro bus service increases by 0.1%. Lower travel cost of metro bus attracts the lower and middle income groups to shift their travel mode from public transport to metro bus. Notably, the regression coefficient of travel time is also positive, indicating that travel time increases the probability of travelers to shift to metro bus by 0.991 units. As travel time for public transport increases, the likelihood to travel by metro bus service increases by 0.8%.

Model 4b i.e. metro- own transport model, shows the mode shift behavior of own transport users after the introduction of metro bus. The logistic regression coefficient of gender is -0.998, which shows that male travelers are less willing to shift towards metro bus and continue using their own transport. In terms of percentage, males have 63.2% greater odds of using their previous mode of travel as compared to females. Income has no impact on mode shift behavior for health related purpose. The regression estimate of distance is 0.024, which implies that as distance increases, likelihood of own transport users to shift towards metro bus increases by 1.025 units. Further it indicates that each additional kilometer increase in distance increases the log odds of shifting towards metro bus by 2.5%. The regression coefficient of travel cost is -0.0007, indicating that travel cost decreases the probability to shift to metro bus service by 0.999 units. It is obvious that patients have to visit hospitals regardless of the fare charged by any kind of transport. The log odds of not shifting towards metro decreases by 0.1%. Travelers who are sick and not able to come to metro stations, might prefer using own transport. The logit estimate of travel time is -0.017, which explains that, own transport travelers are not willing to shift their travel mode towards metro bus, and continue using their own transport due to health and other issues.

Model 4c shows logistic regression results for metro- taxi mode, mentioned in table 5.4. The logistic estimates for gender is -1.582, which indicates that male travelers are less willing to travel by metro as compared to female travelers. It further exhibits that males have 79.5% greater odds of using taxi as female travelers. Like above two models, income has no impact on taxi travelers. The logistic regression coefficient of distance is -0.019. Odds ratio of distance variable explains that 1 kilometer increase in distance leads to 0.980 units decrease in the likelihood to shift to metro bus. It means that taxi travelers prefer to use taxi for health related purpose when the hospital is at far place from their residence. The regression coefficient of travel cost is -0.004, indicating that travel cost decreases the probability to shift to metro bus service by 0.995 units. It is obvious that patients have to visit hospitals regardless of the fare charged by any kind of transport and they continue using taxi for visiting hospital. The logit estimate of travel time is -0.072, which explains that, taxi users are not willing to shift their travel mode towards metro bus, and continue using their own transport due to health and other issues.

The pseudo R square for metro-public is 0.0214 means that 2% variation in the model is explained by explanatory variables, the pseudo R square for metro-own is 0.0741, shows that 7% variation in model is explained by explanatory variables and the pseudo R square for metro-taxi model is 0.3115, means that 31% variation is explained by explanatory variables in the model.

5.2.5. Model 5- Logistic Regression Model for Friend/Family Visit Purpose:

Table 5.2.5: Logistic Regression Model for Friend/Family visit Purpose

	Model 5a			Model 5b			Model 5c		
Variables	**β**	**odds Ratio**	**%**	**β**	**Odds Ratio**	**%**	**β**	**Odds Ratio**	**%**
Gender	0.579 (0.346)	1.785	78.5	2.455 (0.000)	11.649	1065.0	2.966 (0.000)	19.416	1841.6
Income	0.000 (0.66)	1.000	0.0	0.000 (0.277)	1.000	0.00	0.000 (0.950)	1	0.000
Distance	0.011 (0.80)	1.012	1.2	0.083 (0.011)	1.086	8.7	0.026 (0.470)	1.027	2.7
Travel Cost	0.002 (0.007)	0.997	0.2	-0.0005 (0.120)	0.999	-0.0	0.0016 (0.002)	0.998	0.2
Travel Time	0.017 (0.08)	1.017	1.87	0.059 (0.000)	1.061	6.1	0.069 (0.000)	1.071	7.2
Constant	-2.343 (0.008)	0.095	.	-6.230 (0.000)	0.001	.	-6.4245 (0.000)	0.001	
Observations		223			114			108	
Pseudo R^2		0.1336			0.2761			0.4292	

Table 5.2.5 shows the logistic regression results estimated from equation 5 for model 5 i.e. when the dependent variable is taken as friends/family visit. This table exhibits the mode shift behavior of public transport, own transport and taxi users after the introduction of metro bus

Model 5a i.e. metro- public transport model, explains the logistic regression results for metro-public transport model, when the dependent variable is friends/family visit. The logistic regression estimate of gender variable is 0.579, which shows that male travelers are more willing to shift towards metro bus from public transport as compared to female travelers. It also illustrates that male travelers have 78.5% greater odds to shift towards metro bus service. There is no impact of income on mode shift behavior. The logit estimate of distance is 0.011. Odds ratio of distance variable explains that if distance increases by one kilometer, then the likelihood to shift towards metro increases by 1.012

units. In terms of percentage, the log odds to shift towards metro from public transport increases by 1.2%. The regression coefficient of travel cost is 0.002 and is also significant. Lower cost for metro attracts the passengers of public transport mode by 0.2%, when the purpose of travelers is to visit friends and family. Whereas the odds ratio of this variable indicates that with 1PKR increase in cost for public transport leads to 0.997 units increase in mode shift behavior towards metro bus service. Correspondingly, travel time has the logit estimate of 0.017 and is significant at 0.1 significance level. Odds ratio of this variable indicates that each additional minute spent on travel time for public transport leads to the increased likelihood to travel by metro by 1.017 units. The mode shift due to travel time reduction towards metro is 1.87%. The main reason behind this shift is metro has a separate route and is time efficient mode of transport as compared to public transport.

Model 5b i.e. metro- own transport model, explains the logistic regression results for metro-own transport model, when the dependent variable is friends/family visit. The logistic regression estimate of gender variable is 2.455, which shows that male travelers are more willing to shift towards metro bus as compared to female travelers. It also illustrates that male travelers have 1065.0% greater odds to shift towards metro bus service. There is no impact of income on mode shift behavior. The logit estimate of distance is 0.083. Odds ratio of distance variable explains that if distance increases by one kilometer, then the likelihood to shift towards metro increases by 1.086 units. In terms of percentage, the log odds to shift towards metro from own transport increases by 8.7%. The regression coefficient of travel cost is -0.0005. It means that these travelers are willing to travel by their own transport regardless of high travel cost borne by them while using own transport. Travel time has the logit estimate of 0.059 and is significant at 0.01 significance level. Odds ratio of this variable indicates that each additional minute spent on travel time for own transport leads to the increased likelihood to travel by metro by 1.061 units. The mode shift due to travel time towards metro is 6.1%. The main finding of metro-own transport mode is that travel time is considered as a key factor in shifting the transport mode. Own transport travelers tend to shift towards metro because of time factor and they are giving less importance to travel cost.

Model 5c, explains the logistic regression results for metro-taxi model, when the dependent variable is friends/family visit. The logistic regression estimate of gender variable is 0.966, which shows that male travelers are more willing to shift towards metro bus from public transport as compared to female travelers. It also illustrates that male travelers have 1841.6% greater odds to shift towards metro bus service. There is no impact of income on mode shift behavior. The logit estimate of distance is 0.026. Odds ratio of distance variable explains that if distance increases by one kilometer, then the likelihood to shift towards metro increases by 1.027 units. In terms of percentage, the log odds to shift towards metro from public transport increases by 2.7%. The regression coefficient of travel cost is 0.0016 and is also significant. Lower cost for metro attracts the passengers of taxi mode by 0.2%, when the purpose of travelers is to visit friends and family. Whereas the odds ratio of this variable indicates that with 1PKR increase in cost leads to 0.998 units increase in mode shift behavior towards metro bus service. Correspondingly, travel time has the logit estimate of 0.069 and is significant at 0.1 significance level. Odds ratio of this variable indicates that each additional minute spent on travel time for taxi leads to the increased likelihood to travel by metro by 1.071

units. The mode shift due to travel time metro is 7.2%. The main reason behind this shift is metro has a separate route and is time efficient mode of transport as compared to public transport.

The pseudo R square for metro-public is 0.1336, shows 13% variation in model is explained by explanatory variables, whereas, the pseudo R square for metro-own transport is 0.2761, shows that variation explained by explanatory variables is 27.6% in the model, while, the pseudo R square for metro-taxi model is 0.4292, which also shows that 42.9% variation in the model is explained by explanatory variables.

5.2.6. Model 6- Logistic Regression Model For Social Activities:

Table 5.2.6: Logistic Regression Model for Social Activities Purpose.

	Model 6a			**Model 6b**			**Model 6c**		
Variables	**β**	**odds Ratio**	**%**	**β**	**Odds Ratio**	**%**	**β**	**Odds Ratio**	**%**
Gender	1.1941 (0.023)	3.300	230.1	0.826 (0.017)	2.285	128.5	0.120 (0.891)	1.128	12.8
Income	0.000 (0.923)	1.000	0.0	0.000 (0.829)	1.000	0.00	-0.000 (0.315)	0.999	-0.0
Distance	0.011 (0.764)	0.988	1.1	0.021 (0.466)	1.021	2.1	0.243 (0.024)	1.275	27.5
Travel Cost	0.0009 (0.04)	0.999	0.1	0.0003 (0.145)	1.0002	0.0	0.0029 (0.000)	1.002	0.3
Travel Time	-0.008 (0.64)	0.991	-0.9	-0.033 (0.056)	0.966	-3.3	-0.064 (0.429)	0.937	-6.3
Constant	1.869 (0.014)	0.154	.	-2.0703 (0.001)	0.126	.	-5.507 (0.055)	0.004	
Observations		223			114			108	
Pseudo R^2		0.0840			0.4648			0.0383	

Table 5.2.6 exhibits the logistic regression results for three travel modes, when the purpose is social activities as already mentioned in model 3 in chapter 4.

In model 6a, i.e. metro- public mode for social activities purpose, the logit estimate of gender is 1.194, shows that male travelers are more willing to shift their mode of travel towards metro bus as compared to females. The probability of male travelers to shift to metro bus increases by 230.1%. Income has no effect on shift mode. The regression coefficient of distance is 0.011, which shows a positive relation between distance and mode shift behavior. Odds ratio of distance explains that one kilometer increase in distance leads to 0.988units increase in the mode shift behavior of public travelers towards metro bus, whereas in terms of percentage, with additional kilometer increase in distance, increases the log odds to shift towards metro bus increases by 1.1%. The logit estimate of travel cost in metro-public mode is 0.0009 and it is statistically significant at 0.05 significance level. Lower cost for metro attracts the passengers of other modes by 0.1% for shopping purpose, whereas the odds ratio of this variable indicates that with 1PKR increase in cost for public transport leads to 0.999 units increase in mode shift behavior towards metro bus service. Correspondingly, travel time has the logit estimate of -0.008. Odds ratio of this variable indicates that each additional minute spent on travel time for public transport leads to the decreased likelihood to travel by metro by 0.991 units. This means that public transport users are not affected by long duration of trips. The major factor for their shift is reduced cost of metro bus.

In model 6b, where metro-own transport model is estimated for social activities. In explaining gender variable, the logit estimate of this variable is 0.826, which indicates that male travelers are more willing to shift their travel mode to metro bus for social purpose as compared to female travelers. In terms of percentage, there is 128.5% increase in mode shift behavior of male travelers. In this case, income again has no impact on mode shift behavior. Distance has the logit coefficient of 0.021, which shows a positive association with mode shift to metro for own transport users. Odds ratio of distance interprets that one kilometer increase in distance leads to 01.021 units increase in the likelihood to shift towards metro bus service. Furthermore, the log odds to shift to metro increases by 2.1%. The logistic regression coefficient of travel cost variable is 0.0003. Moreover, the odds ratio of this variable indicates that with 1PKR increase in cost of own transport leads to 1.0002 units increase in mode shift behavior towards metro bus service. Likewise, travel time has the logit estimate of -0.033. Odds ratio of this variable indicates that each additional minute spent on travel time for own transport leads to the decreased likelihood to travel by metro by 0.966 units. This means that own transport users are not affected by long duration of trips. The major factor for their shift is reduced cost of metro bus.

As for model 6c i.e. metro-taxi model, the logistic regression results of this model are mentioned here for social activities purpose. Starting from gender variable, the logit estimate of gender is 0.120, shows that male travelers are more willing to change their travel mode from taxi to metro bus as compared to female travelers. The probability of male travelers to shift to metro increases by 12.8%. Again income has no impact on mode shift behavior, but its coefficient is negative, which interprets that as income tends to rise, travelers use taxi for social activities and not preferring metro bus service. Next, the logit estimate of distance variable is 0.243. It shows a positive association with mode shift to metro bus. Odds ratio interprets that with each additional kilometer increase in distance, increases the mode shift behavior towards metro bus by 1.275 units. It further explains that if distance increases by one kilometer, then the log odds for shifting towards metro mode from taxi mode increases by 27.5%. The logistic estimate of travel cost is 0.0029. This variable is statistically significant at 0.011 significance level. In terms of percentage, as travel cost of taxi increases, the log odds for mode shift towards metro bus increases by 0.3%. The logit coefficient of travel cost variable is -0.064. As travel time of taxi increases, the likelihood to shift towards metro from taxi mode decreases by 6.3%. This means that taxi users are not affected by long duration of trips. The major factor for their shift is reduced cost of metro bus.

The pseudo R square for metro-public transport is 0.0840, shows that 8% variation in the model is explained by explanatory variables, while, the pseudo R square for metro-own transport is 0.4648, which also exhibits that 46% variations in the model is explained by explanatory variables, whereas the pseudo R square for metro-taxi model is 0.0383, shows 38% variation in the model is explained by explanatory variables.

5.3. Carbon Emission Reduction:

According to "Excise and Taxation Department, Islamabad Capital Territory" (2017) a total of 700 public vans are replaced after the implementation of metro bus service in the region. These vans traveled at a distance of 25 kilometers daily on routes 1 and 1c, which were now replaced by metro route. These vans made 5-6 trips daily on these routes. Emissions from three propulsion systems i.e. petrol, diesel and CNG are calculated and then compared by the emissions of metro bus.

According to "Ecoscore" (2017) and "Company Car Tax Calculator" (2017) standard calculations for CO_2 emission level from fuel consumption are given below:

- 1 liter of petrol emits 2392 grams of CO_2.

- 1 liter of diesel emits 2640 grams of CO_2.
- 1 kilogram of CNG emits 2666 grams of CO_2.

Older engines might lose a few percent due to unburnt fuel, but otherwise technology can have little effect on this chemistry ("Company Car Tax Calculator", 2017).

Table 5.3.1 Fuel Consumption and CO_2 Emissions:

Propulsion System	Consumption /trip/vehicle (Liters)	Consumption/700 vehicles/day (Liters)	CO_2 Emissions/liter (Grams)	CO_2 Emissions/day (Metric Tons)	CO_2 Emissions/day (Metric Tons)
Petrol	3 Liters	25200 Liters	2392 Grams	60.27	18083
Diesel	2.5 Liters	21000 Liters	2640 Grams	55.44	16632
CNG	2 Kg	16800 Kg	2666 Grams	44.78	13437

Table 5.3.1 shows the consumption of fuels by vehicles having different propulsion systems. If the propulsion system of these vehicles is petrol, then approximately 3 liters of petrol is used for covering a distance of 25 kilometer by a single vehicle. For 12 trips per day by 700 vehicles, the amount of fuel consumption is 25200 liters. If 2392 grams of CO_2 are emitted from 1 liters of petrol, then 60.20 metric tons of carbon is emitted per day and 18083 metric tons of carbon are emitted per year from vehicles using petrol.

If the propulsion system of these vehicles is diesel, then approximately 2.5 liters of diesel is used for covering a distance of 25 kilometer by a single vehicle. For 12 trips per day by 700 vehicles, total fuel consumed is 21000 liters. If 2640 grams of CO_2 are emitted from 1 liters of diesel, then 55.44 metric tons of carbon is emitted per day and 16632 metric tons of carbon are emitted per year from vehicles using diesel.

2 kg of CNG is used for covering a distance of 25 kilometer by a single vehicle. For 12 trips per day by 700 vehicles, total CNG consumed is 16800 kg. If 2666 grams of CO_2 are emitted from 1 kg of CNG, then 44.78 metric tons of carbon is emitted per day and 13437 metric tons of carbon are emitted per year from vehicles using CNG.

Fuel Consumption of Metro Bus:

On the other hand, a total of 60 buses travel across this route, covering a distance of 16906km and daily consumption of diesel is 9798liters.

I liter diesel = 2640grams of CO_2

9798 liters = 25,866,720 grams of CO_2/day

300*25,866,720 = 7,760,016,000 grams of CO_2/anum.

7760 metric tons of CO_2 emitted from metro buses per year.

5.3.2. Reduction in CO_2 Emissions:

5.3.2: Reduction in CO_2 Emissions.

Propulsion System	CO2 reduction (metric tons/anum)
Petrol	10323.5
Diesel	8872
CNG	5677

It is obvious from table 5.3.2, that metro bus service has reduced the significant amount of carbon emissions by replacing public vehicles from the route, subsequently cleaner air quality is achieved. It is evident from the table that if the replaced vehicles used petrol, then around 10323.5 metric tons of carbon emissions are reduced. Similarly if the replaced vehicles used diesel, then 8872 metric tons of carbon emissions are reduced, whereas for CNG vehicles, 5677 metric tons of carbon emissions are reduced annually. It is concluded that metro bus service has contributed in cleaner air quality of the region.

Chapter 6

CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

This study used logistic regression method to analyze the survey data associated with the metro bus service in Islamabad- Rawalpindi, twin cities in Pakistan and examine mode shift behavior for shift to metro service for public transport, own transport and taxi users. Factors that are statistically significant in affecting model shifts to metro bus service include trip distance, travel cost and travel time of commuters. From the survey data of metro bus service, it is found that 18% of metro passengers were former public transport users and own transport and taxi users together comprised 17% metro travelers. In the prior studies, the modal shift was 50% from bus and train users and 27% from car users (Knowles, 1996). The new metro in Athens has attracted 53% of bus passengers and 16% of former car travelers (Golias, 2002). In the Madrid subway project, 50% of passengers were former bus users, and 26% of passengers used to travel by car (Monzon, 2000). Finally, 69% of Tramlink passengers were bus users and 19% of passengers were former auto travelers in Croydon (Copley et al. 2002). The comparisons among Pakistan metro bus and other cities indicate that mode shifts to newly introduced metro from public transport closely resemble one another. Another interesting finding can be seen from gender factor that a negative signs of gender variable in the overall models indicate that women travelers are more likely than men to use metro. This conclusion is inconsistent with prior research findings (Patterson et al. 2005; Enam and Choudhury, 2011; Rahul, 2011), presenting that female travelers are reluctant to include public transport modes in their choice sets. Income showed no impact on mode shift behavior.

Secondly, this study intended to found the reduction in travel cost and travel time due to implementation of metro bus system. According to the results almost PKR 801 to PKR 1091 and travel time of around 23 minutes are reduced respectively for metro bus commuters. This conclusion is consistent with prior research findings (Domencich et al. 1968; O'Sullivan, 2000; Golias, 2002; Levinson et al. 2013; Wang et al. 2013).

Lastly the study found that metro bus service has replaced around 700 public vehicles from the route of metro bus. It is estimated that approximately 800 metric tons of carbon emissions are reduced from the city so far. In the previous studies, nearly 1 million of carbon is reduced per year in Bogota (Turner et al. 2012), around 167 tons of carbon emissions are reduced daily in Istanbul (Alpkokin and Ergun, 2012). Levinson et al. (2013) have found out that with the launch of metro bus, around 80,000 vehicles reduced from the road and hence 623 tons of CO_2 is reduced on daily basis.

6.2. Policy Recommendations

Some important recommendations are as under:

- Future expansion of metro route needs to be implemented to formulate an integrated network within the city.
- More travel time could be saved by extending metro route in congested areas.
- Metro route should be extended in such a way that students and employees can easily reach their respective institutions.

- Ring Road as constructed in Lahore, should also be constructed in Rawalpindi-Islamabad so that it covers a larger area and more stations of metro bus service can be built on that route.
- More buses are required in the existing fleet, to reduce the congestion within buses.
- Moreover, some policies such as implementation of park and ride facilities may be effective in attracting more passengers from own transport mode towards metro bus service.
- The impacts on easing traffic congestions by a single metro corridor are not significant, and some parallel policies need to be adopted for the support of metro services such as construction of overhead bridges and underpasses.

6.3. Limitation and Future Work

This study only surveyed the users of metro bus service, non-users of metro bus service could be surveyed as well. In future studies, the land use variables such as residential density need to be included in models and conducting an economic cost-benefit evaluation may shed more light on the economic feasibility of metro bus service.

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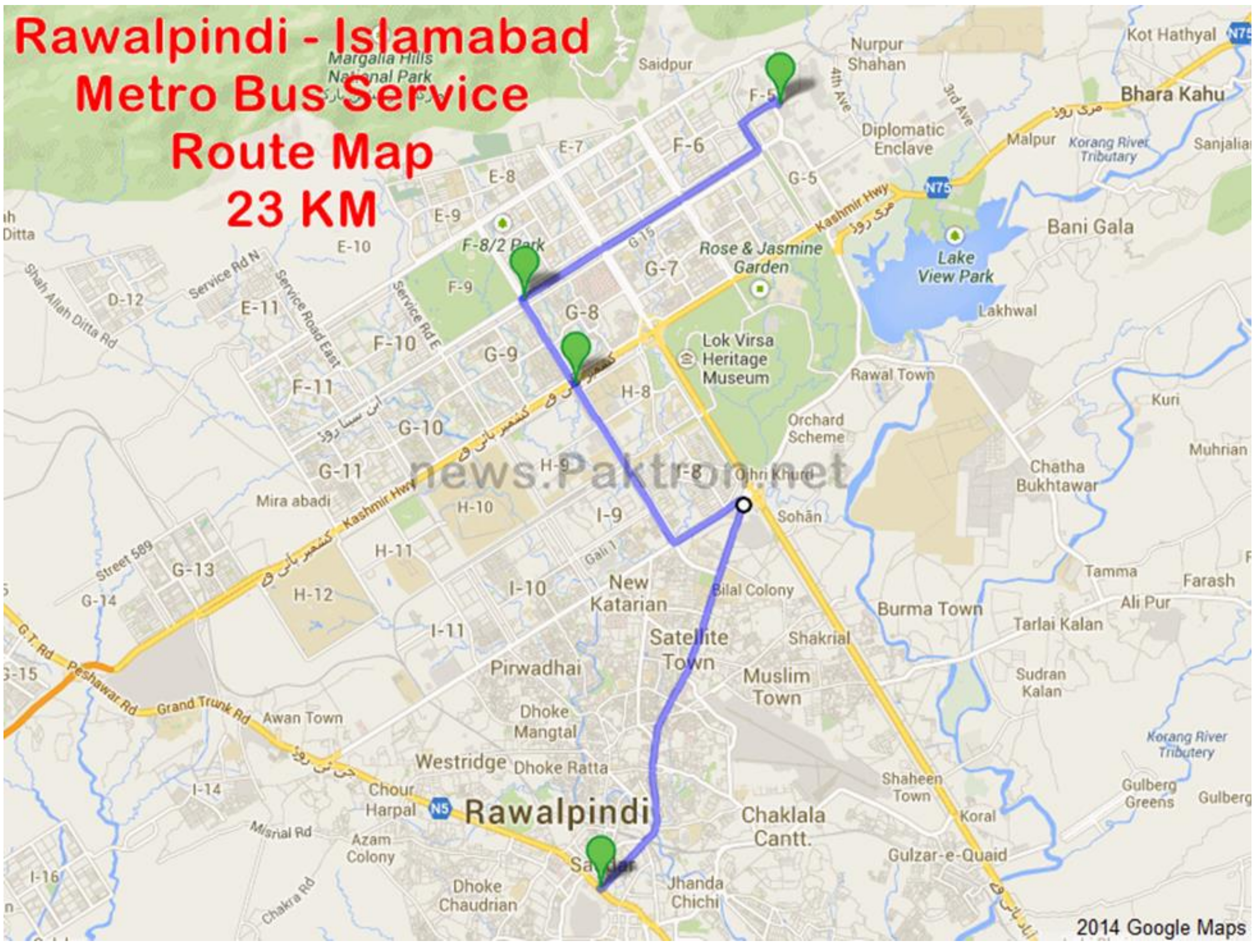
APPENDIX 1

Indicator	Value	Date	Source
System name (System info)	**Rawalpindi-Islamabad Metrobus**	**2015**	**www.metrobus.com.pk**
Corridors (System info)	1	2015	www.pakistantimes.com
Year system commenced (System info)	2015		www.pakistantimes.com
Transit agency (System info)	Punjab Metrobus Authority		rawalpindi.gov.pk
Peak load (passengers per hour per direction) (System info)	2,100	2015	www.worldbrt.net
Daily demand (passengers per day) (System info)	125,000	2015	www.worldbrt.net
Annual demand (passengers per year) (System info)	37,500,000	2012, estimated demand	Calculated using daily demand and 300 working days
System length (km) (Additional Information)	22,50		www.metrobus.com.pk
Stations (Additional Information)	22	2015	www.metrori.pk
Station spacing (m) (Additional Information)	1022,7	2015	Calculated using system length and stations
Pre-board fare collection (Additional Information)	All	2015	www.metrori.pk
Total fleet (System fleet)	68	2015	www.pakistantimes.com

APPENDIX 2

Route Map of Rawalpindi- Islamabad Metro Bus Service



APPENDIX 3

Nearest Famous Places From Metro Bus Stops.

Stations	Near By Places
Saddar	Bank Road, Railway Station, CMH, AFIC, CSD, GPO, Cantonment General Hospital.
Liaquat Bagh	Raja Bazar, RDA, Gorden College, Savour Foods.
Committee Chowk	District Head Quarter Hospital, Raja Bazar, Rawal Road, Punjab Institute Of Cardiology.
Waris Khan	Bani, Jamma Masjid Road, Sarafa Bazar, Naz Cinema.
Chandani Chowk	Central Hospital, Rawal Road, Holy Family, Asghar Mall
Rehmanabad	Commercial Market, Sadiqabad.
6th Road	Govt. Post Graduate College, 6th Road, Govt. College Satellite Town.
Shamsabad	Pir Mehar Ali Shah University, Nawaz Sharif Park, Double Road, Rawalpindi Cricket Stadium, Food Street, Art Council.
Faizabad	Bus Stops (Addah), Rawal Dam, Islamabad Highway.
Ijp	Pendora Chungi, Double Road, Food Street, Stadium, Pirwadahi Road.
Potohar	I-9 Markaz, I-8.
Khayban-E-Johar	Margalla Railway Station, NUML, Sui Northern Gas, Industrial Area.
Faiz Ahmed Faiz	HEC, Polytechnic College, Zabist, National Language, Federal Board, Education, H-8 Graveyard.
Kashmir Highway	Motorway, Golra, FIA Head Quarter, Allama Iqbal Open University, Hilal-E-Ahmer, Sunday Bazar, Peshawar More, Nadra, EOBI, NUST, Zero Point, PID, Islamic University.
Chaman	Karachi Company, Mazoor Hospital.
Ibn-E-Sina	F-9 Park, Katchery.
Katchery	F-9 Park, Katchery.
PIMS	PIMS, Faisal Masjid, Zoo, Daman-E-Koe.
Stock Exchange	Saudi Pak Tower, Stock Exchange Building.
7th Avenue	Jinnah Super, Food Street, Lal Quarters, Satara Market.
Shaheed-E-Millat	Poly Clinic, Aabpara, Press Club, Super Market, Melodi Food Street, GPO.
Parade Ground	Marriet Hotel, Pakistan National Council Of Arts.
Pak Secretariat	Prime Minister Secretariat, KPK House, Sindh House, Baluchistan House, Kashmir House, Punjab House, President House.

APPENDIX 4

Survey Questionnaire

Environmental Impact Analysis of Metro Bus Service
(Case Study of Islamabad-Rawalpindi)

We sincerely request you to fill in the important information required in this questionnaire. Please answer the questions as honest as possible. We assure you that all responses will be kept secretly confidential.

Section A: Commuters' Characteristics:

1. **Name**: ________________ (Optional)

2. **Gender:**

   ☐ Male ☐ Female

3. **Age:** __________

4. **Total Family income: (in Rs.)** ______________

5. **Education:**

   ☐ Illiterate ☐ Primary ☐ Middle ☐ Matric

   ☐ Intermediate ☐ Graduate ☐ Masters

6. **Occupation:**

   ☐ Student ☐ Government Servant ☐ Employment in Private Sector

   ☐Manual Worker (labor) ☐ Business/Trade ☐ Household Women

   ☐ Banker ☐ Doctor/Nurse ☐ Other_____________

7. **Residential Address:** ______________________

8. **What is your starting point on metro?** ____________________

9. **What is your destination? ____________________**

10. **What is your egress station? __________________**

11. **Do you have your own transport?**

☐ Yes ☐ No

12. **Type of Transport you have?**

☐ Car ☐ Bike ☐ Cycle

13. **The use of own transport is for:**

☐On metro route

☐Other than metro route

Section B: Metro bus/Travel Characteristics:

14. **Have you ever travelled by Metro bus before?**

☐Yes ☐ NO

15. **Do you prefer to travel on metro bus with family on metro route?**

☐ Strongly disagree ☐ Disagree ☐ Uncertain

☐ Agree ☐ Strongly agree

16. **Your preference to travel on other areas on metro (where metro is not available):**

☐________________ ☐_________________

☐________________ ☐__________________

17. **How often do you travel by Metro bus?**

☐ Daily ☐ Numbers in week____________

☐ Weekends

18. **What is the most frequent purpose of your trip?**

☐ Job ☐ Education ☐ Shopping ☐ Hospital

☐ Friend/family visit ☐ Social Activities ☐ Other________________

19. What are the reasons of using metro bus?

☐ Fast ☐ No traffic Congestion ☐ Comfortable ☐ Economical/cheap
☐ Frequent service ☐ Safety/security ☐ Have no other choice

20. What is your access mode to metro bus?

☐ Walk ☐ Private Bus ☐ Public bus ☐ Private car ☐Taxi

21. How do you reach to your destination after metro bus?

☐ Walk ☐ Private Bus ☐ Public bus ☐ Private car ☐ Taxi

22. Your estimated monthly travelling expense:

☐ On metro___________________ ☐ On taxi___________________

☐ When no metro (1# route) _________________ ☐ On own transport_____________

23. How much time is taken for journey towards destination?

☐ Without metro bus service -------------------------------

☐ With metro bus service -----------------------------------

24. Before the launch of metro, how do you travel?

☐ Walk ☐ Private Bus ☐ Public transport ☐ Private car ☐ Taxi

25. Your satisfaction level regarding metro bus service?

☐ Unsatisfied at all ☐ Unsatisfied ☐ Neither satisfied nor unsatisfied

□ Satisfied □ Very satisfied

26. In general, do you have a positive or negative opinion of the usefulness of Metro bus service?

□ Positive □ Negative □ Do not know

27. Do you think Metro bus service will help in reducing traffic congestion in the city?

□ Yes □ No □ Do not know

28. Do you think Metro bus service will make it more convenient for you to get around different places in the city?

□ Yes □ No □ Do not know

Thanks for your time

.