# ANALYSIS OF FACTORS INFLUENCING METRO RIDERSHIP IN RAWALPINDI

**FINAL YEAR PROJECT UG 2017**

By


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This is to certify that the

Final Year Project Titled

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has been accepted towards the requirements for the undergraduate degree

**in**

**CIVIL ENGINEERING**


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# ABSTRACT

Globally, Bus Rapid Transit (BRT) used on urban transportation networks as a substitute to private mode trips specially to address peak-time congestion The Government of Pakistan has initiated various mass-transit projects in cities of major and/or metropolitan characteristics, and Rawalpindi/Islamabad is one of them. In Rawalpindi city, metro line has been functioning since year 2015. The objective is to provide effective and sustainable service for public, especially for the private mode users. Therefore, without being analyzed, one cannot assess about a shift in ridership. In our study, we have analyzed an impact of factors (e.g., fare, travel time) that influence on ridership. Additionally, we have considered an effect of pandemic (COVID-19) situation on the ridership based on the busiest stations of Rawalpindi (i.e., Committee Chowk, Faizabad, and Saddar). We had developed scenarios of "Do-Minimum" (two-year plan) increasing bus fare in peak hours, decreasing travel time between the busy stations). Whereas the "Do-Something" scenarios mostly include those measures that have a long-impact and cross-elastic in relationship to an effect on transit ridership (such as fuel price, park and ride, road congestion etc.). Our study results have showed that an additional dedicated bus service for peak hours for covering busy stations only would attract more riders than any other cases of change in fare. Thus, there is a need to carryout detailed further study that would assist policy makers in public sector in predicting the out-falls from proposed policies and newly introduced interventions, whether be acceptable to users or public. In addition, it would intimate about initiatives on mega-transit schemes be able to serve value to money to the treasury.



**Keywords**: Mass Transit, Ridership, Demand, Elasticity, Fare, and Travel Time

## DEDICATED

To my loving parents, teachers, friends, and my colleagues.

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Additionally, we would like to express our indebtedness to Shumaila Mohsin, Manager Operations (Technical), PMBS Authority, and Mr. Muhammad Qasim, Assistant Manager (Operations), PMBS Authority for their kind support in data acquisition, and professional advices throughout this project.

## Table of Contents

# List of Figures

# List of Tables

# List of Abbreviations

| | |
|---|---|
| HOV | Highly Occupancy Lanes |
| CDA | Capital Development Authority |
| RDA | Rawalpindi Development Authority |
| AIC | Akaike Information Criterion |
| IGC | International Growth Center |
| TOD | Transit-Oriented Development |
| CBD | Central Business District |
| AFCS | Automated Fare Collection System |
| PMA | Punjab Masstransit Authority |
| DM | Do Minimum |
| DS | Do Something |

# CHAPTER 1

## INTRODUCTION

### 1.1 General

Metroline is a public transportation vehicle that was created by the combination of metro and rail systems. Unlike bus systems, the Metroline runs follows the concept of guided bus service wherein dedicated route to for its service (What is Metrobus?, 2020). Also, another difference from bus systems is that the stops are pre-paid i.e., tickets are bought and paid for before the entry of the passenger and the station-to-station distance is longer in the Metroline. Metroline has proven to be efficient service in handling congestion. Globally, major cities of urban and metropolitan nature have significantly successful in achieving model shift from private based trip to public mode of journey through metro line projects. In this way, it is capable of handling various urbanization issues related to increase in population, congestion, safety, and vehicle operating cost, etc. that contributed heavily to economy at macro and micro level. Urban areas having frequent delays over the entire road network causes a great strain on current public transportation systems and services. Hence, a guided bus system using a separated track, and /or in form of Highly Occupancy Lanes (HOV) has proven as an alternative way to handling those urban issues. Additionally, it is designed to attract or focus people belong to all occupations. Else, the objectives that are meant to achieve from such mega-projects would become a question itself.

This is a behavior that we have come across on our subject area (Rawalpindi metro line project) where the no significant improvement has been observed over the road network since the introduction of the metro line. Additionally, since its start, it has come under intense scrutiny with critics claiming that it was not working at its full capacity. Whereas the public agencies (CDA and RDA) have offered users with a huge amount of subsidies. Some critics have highlighted about the negligence at administrative and planning level in handling project that make it too expensive, claiming the annual loss of 28 percent (since each bus costs Rs. 9100 and earns only Rs.2600 according to un-official statements (Salman, 2015)). Initially, it gives service at a fixed fare price irrespective of the trip origin and destinations. Later, the public agency has introduced a destination-based trip fare rates which seems to be more realistic strategy. Additionally, raising the fare price based on the passenger's willingness to pay is a much better alternative. However, once cannot say that these critics were right in their claim. It is said so because first, these are long-term based project that have been accessed in term of user's benefits, which is different than running a private mode services (aim to get benefits in term of profit). Secondly, there were private routes in placed that this metro line has replaced. So, we can say that the existing public user has shifted to this metro line. Else, there would be a significant change could be observed over the road-network with the start of the metro line. This also indicates that there is still needed to do a lot of work in achieving objectives of metro line specially in compelling shift from private mode trips to public mode trips. This work focuses mainly on obtaining of the demands for the Metro Bus in the light of various factors like travel time, fare change, Pandemic.

### 1.1.1 Study Area

The complete Metro bus network is 22.5 km long with 24 stations, from the Saddar station in Rawalpindi to the Pak secretariate in Islamabad. Our study area includes the Rawalpindi section of the Metro bus that consists of 11 stations from Saddar station to IJP station. Out of these 11 stations, we further filtered out three stations based on the highest number of ridership either in boarding or alighting. These three stations are Saddar, Committee Chowk and Faizabad. These three stations were representative for our 11 stations in our whole study area.

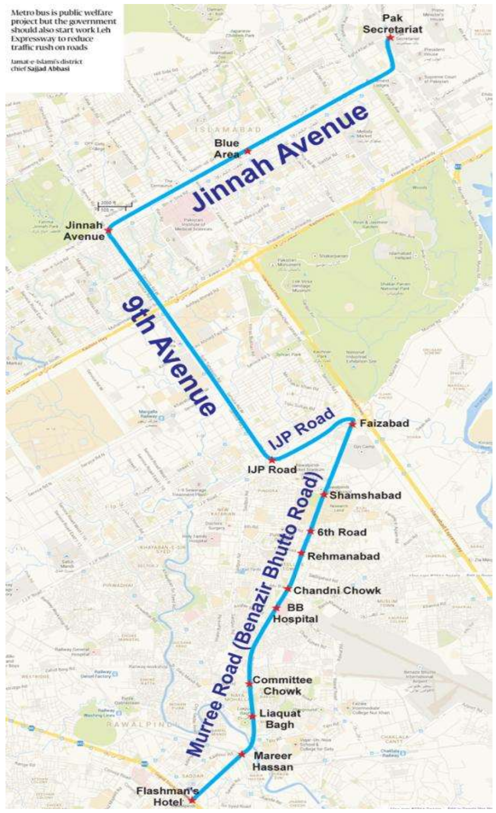


Figure 1: Rawalpindi-Islamabad Metro Bus Route

### 1.1.2 Bus Frequency

During peak hours (7:16 AM to 9:26 AM & 3:20 PM to 5:40 PM) 32 buses (i.e., 30 buses on track, while 2 buses as backup) are operative in one direction with headway of 1.875 minutes. Although this headway has increased to almost 3 minutes during the pandemic.

Seating Capacity in each bus is 160 Passengers (Standing + Seating (42))

While on average for the month of January 2019, 13 trips per bus per day were taken.

### 1.1.3 Fare Change

In the Past six years of operation of Rawalpindi Metro Bus, there are few studies done related to the relationship of different factors like Fare change, Population increases etc. on the ridership of the Metro Bus. In the contemporary world, all such studies go along with the operation of metro bus services, as they help the policy makers make the right decision about the metro service.

In the case, if an elasticity value is high, it indicates that the product/good is price sensitive. It means that a small change in price causes large change in consumption.

Similarly, a low elasticity value means that prices have less impact on consumption. In August 2019, fare of Metro Bus was increased for the first time after 4 years of operation, since it started in 2015, by ten rupees. How this change affected the ridership is a major part of our study.

### 1.1.4 COVID-19

Pandemic hit the public transport sector very hard. Pakistan was hit with the Pandemic in March 2020 but covid started in December 2019, and as the situation got serious, the metro bus was completely shut down for four months from April to July and then the service resumed in the month of August.

According to data from Google mobility **reports**, visitors to all public transit locations – such as bus services, terminals, and waiting areas – have fallen by as much as 80% across IGC (International Growth Center) countries since early March. Many operators have had no choice but to scale back or completely shut down less viable routes, while others are passing their costs onto consumers. While visits have been steadily rising since, the threat of sharp restrictions still loom for many of the poor and disadvantaged who have few alternatives.

### 1.1.5 Purpose

The purpose of this study is to see how strategies in form of policy change in fare price and travel time would influence the ridership of the transit. The city like Rawalpindi having urban characteristics with a various kilometer of downtown areas as business and commercial hub, would respond. Also, the influence of factors related to either come under direct relationship to elasticity or indirect on long term ridership of this scheme. There are various other issues associated with this city wherein the most concern is increase in population. If this trend of population increases in persistent in a similar fashion, then what where the mitigation required by the government and public agencies to achieve sustainability objectives. Additionally, the recent pandemic situation has proven as adding more sugar to a custard, which required extra effort to be in place for current and in future perspective. The metro line at twin cities (Rawalpindi/Islamabad) covers Murree-road of Rawalpindi and 7$^{th}$ avenue of Islamabad up to secretariat connecting to Srinagar Highway. However, both cities have difference very far apart in traffic behavior and ridership because of the difference in master-planning development procedures adapted at government level.

Therefore, for this study we have chosen our study area concerning Rawalpindi (Murree-road) section of the metro line corridor from Saddar station to Faizabad station, for reasons as aforementioned.

Subsequently, we will try to understand behavior from factors that influencing in gaining trust of this service by making it more attractive to the private mode's users. We will evaluate strategies (e.g., additional bus service for peak hours on high demand stations and distributing demand within peak- and off-peak times) for current and future scenarios. These scenarios would assist in suggesting authorities to adapt various measures and course of action be taken to handle transit demand problems.

### 1.1.6 Significance

This study has a vast significance impact not only to the government (in perspective of providing benefits to users) but has an implication on the society, treasury, and social norms. Moreover, it would lead us towards a way to pursue sustainable and green transportation, green cities, and less carbon footprints. This is only a way of achieving efficiency, effectiveness, and equity on the entire network. Such studies also lead us towards adopting an integrated multi-model approach for transportation systems, wherein achieving financial benefits along with the travel-time savings to all users on the entire network. Based on this preliminary study, it will further generate a healthy debate on the procedural adoption of schemes (e.g., car sharing and pooling, and park and ride) in support of transit at large. Without being considered, the problem of demand on peak and non-peak hours could be difficult to address. It would give a relief in building the framework while working on capacity issues for non-peak hours in comparison with peak times. Furthermore, it would also support reduction in huge waste of both fuel and human resources by moving towards an intelligent based system supported by centrally monitored and controlled data algorithms.

## 1.2 Problem Statement

How is the ridership of metro being affected by various factors? Existing traffic on road network especially during peak hours shows that people prefer to use private vehicles over metro. After the execution of metro, the traffic on road was expected to decrease but various factors impacted this shift such as fare increase, travel time, service etc.

Currently, after the execution of the metro line, it was supposed to attract private road users. It is observed that the situation on the road network for private mode cars-based journey trips have not only remained the same but a trend of an increase in couple of years. This has raised a main concern in the transportation industry and professionals because of an increase in the travel time during peak hours, and this problem is getting worse on daily basis. If this problem persists, and not mitigation strategies adopted at present, the condition on the road network would get to a point of non-bearable to address. This study is a pioneer in focusing analysis-based approach on policy and strategy initiatives, to access its outcomes or pitfalls.

# CHAPTER 2

## LITERATURE REVIEW

Ridership at any station of metro is important for location of any access facilities. Various factors affect travel demand. Some factors are land use, social economics, accessibility, network structure information etc. Different travel patterns according to the time of day are considered and ridership is noted accordingly. Catchment area is taken as 500m as noted by Kim et al for-land use variable. Feeder routes are considered for accessibility factor. Transfer and terminal stations are not used as dummy variables. The population density data in 500m radius is used for social economic variable (He, Zhao, & Tsui, 2018). Commonly used four-step model could also be used but it is best for regional level. So direct demand models based on regression analysis is used. The backward stepwise method according to Akaike Information Criterion (AIC) is used to select variables. Factors for boarding and alighting are not taken separately (He, Zhao, & Tsui, 2018).

Advantages of using direct demand model have been stated by Walters, Cervero and Cardozo et al. as “simplicity of use, easy interpretation of results, immediate response and low cost.” Conclusion was made that commuting activities affects ridership on weekdays and commercial activities affects ridership on weekends. Suggestion given was that TOD (Transit-Oriented Development) planning must be combined with metro network planning (He, Zhao, & Tsui, 2018).

There are multiple factors as to what would affect’s what the consumer chooses the mode to travel on. The main three picked are Density, Diversity and Design. Density is the size of the population area serving the metro station. Diversity is the variation in the land and how it is used. Design is the construction of walkways to the metro station so that the consumer could be motivated to use the transit system (Nyunt & Wongchavalidkul, 2020).

To check the effect of Density, both the Station ridership and the Population Density of the metro bus system are found out. To check the demand of the metro bus system, a relationship is developed between these various variables where some factors are kept constant so that an apt comparison may occur, and a fair result may be obtained.

A correlation analysis is applied on these factors to check the demand of the metro bus system (Nyunt & Wongchavalidkul, 2020).

In any case, price sensitivity is usually measured using elasticities, it is defined as the percentage change in consumption resulting from a one percent change in price, while everything else is held constant. Elasticities are depended on number of factors like, user type, trip type, geography, type of price change, direction of price change, time period, transit type (Paulley & Balcombe, 2006).

In transportation planning, price elasticity has many applications. The prediction of ridership and any revenue effects of change in the transit fares can be done by it. They are also used to predict the change in transit service and their impact on vehicle traffic volumes also pollution emissions. The impacts and benefits of mobility management for new transit services can also be done by it. For transit system to attract more riders and reduce the public automobile travel, fares have to be reduced, and services need to increase. (Paulley & Balcombe, 2006).

It was noted that the more options the consumers have, the more the price increases. Demand is more sensitive to rising fares (-0.4 in the short run and –0.7 in the long run) than to falling fares (-0.3 in the short run and –0.6 in the long run), and that demand tends to be more price sensitive at higher fare levels (Paulley & Balcombe, 2006).

The effect of ridership due to some factors have been studied and concluded by different authors and that are; 1% increase in fare prices will reduce ridership by 0.23%, 1% increase in fare prices will reduce ridership by 0.42% (Pham & Linsalata, 1991), 10% increasing transit in-vehicle travel times for travel is associated with 2.3% decrease in transit demand (Frank, 2008),1 % increase in fare prices will reduce ridership by 0.32% (Kain & Liu, 1999), 10% rise in fuel prices increases transit ridership 1.62% in short run, and 1.2% in long run (TRAC, 1999),Road/parking and congestion prices tend to increase transit ridership 1.75% (Hensher & King, Understanding Transport Demands and Elasticities, 1998),10% increase in prices at preferred CBD parking locations will cause a 3.63%increase in park-and-ride trips (Hensher & King, Understanding Transport Demands and Elasticities, 2001).

A high elasticity value indicates that a good is price-sensitive, that is, a relatively small change in price causes a relatively large change in consumption. A low elasticity value means that prices have relatively little effect on consumption. The degree of price sensitivity refers to the absolute elasticity value, that is, regardless of whether it is positive or negative.

Fare elasticity is a measure of the price sensitivity of bus passengers. Price elasticities have many applications in transportation planning. The factors that influence the fare elasticity are:

- Fare levels: the higher the fare, the more the passengers will be sensitive to the change.
- Size of fare changes: the bigger the change in the fare either positive or negative, the bigger the impact it will have.
- Income levels: it highly depends on the income level of the population living in the catchment area.
- Service quality: The better the service quality provided to the people the more they will try to opt for the public transport rather than their own vehicles.
- Competition from other modes: The greater the competition between the public transport sectors, the more they will perform better, and it will help the public.
- Socio factors: Studies reveal that male are more sensitive to these fare changes compared to women.
- Journey purpose: The purpose of journey whether they are going for work or school etc.
- Distance: Distance plays an important role. If a person is travelling for short distance, the fare change will be higher on him.
- Urban vs Rural – passengers are more sensitive to fare changes in rural areas compared to urban.
- Area – passengers from metropolitan areas are less sensitive to fare changes.
- Peak vs Off Peak – passengers tend to be less sensitive during peak periods of travel, compared with off-peak periods of travel.

After the construction and success of the Lahore Metrobus Project, a meeting was taken place that was co-chaired by the Prime Minister of Pakistan and Chief Minister of Punjab on 19th January 2014. It was decided in this meeting that a similar Metrobus project will begin in Rawalpindi and Islamabad to see the problems faced by the common people who had to traverse daily. The provincial government decided to handle this project through the Rawalpindi Development Authority (RDA) and worked closely with the Capital Development Authority (CDA). Provincial and Federal authorities both have cooperated with each other through these to construct a Metrobus project that would begin from Saddar, Rawalpindi and end up at Pak Secretariat, Islamabad. This project began on 28th February 2014 and was finished in June of 2015 with its opening held on 4 June 2015.

The Rawalpindi-Islamabad Metrobus has two lines with only one of them being operational right now. The operational one runs from Saddar Station to Pak secretariat Station whereas the non-operational line runs from Peshawar Mor Station to Airport Station.

This Metro line transit system uses an AFCS (Automated Fare Collection System) for the boarding and alighting of its passengers. This whole project is run by the Pakistan Metrobus Authority whose office is in Saddar, Rawalpindi. This Metrobus transit system possesses a fleet of 68 articulated 18-meter-long high-floor buses.

# CHAPTER 3

## METHODOLOGY

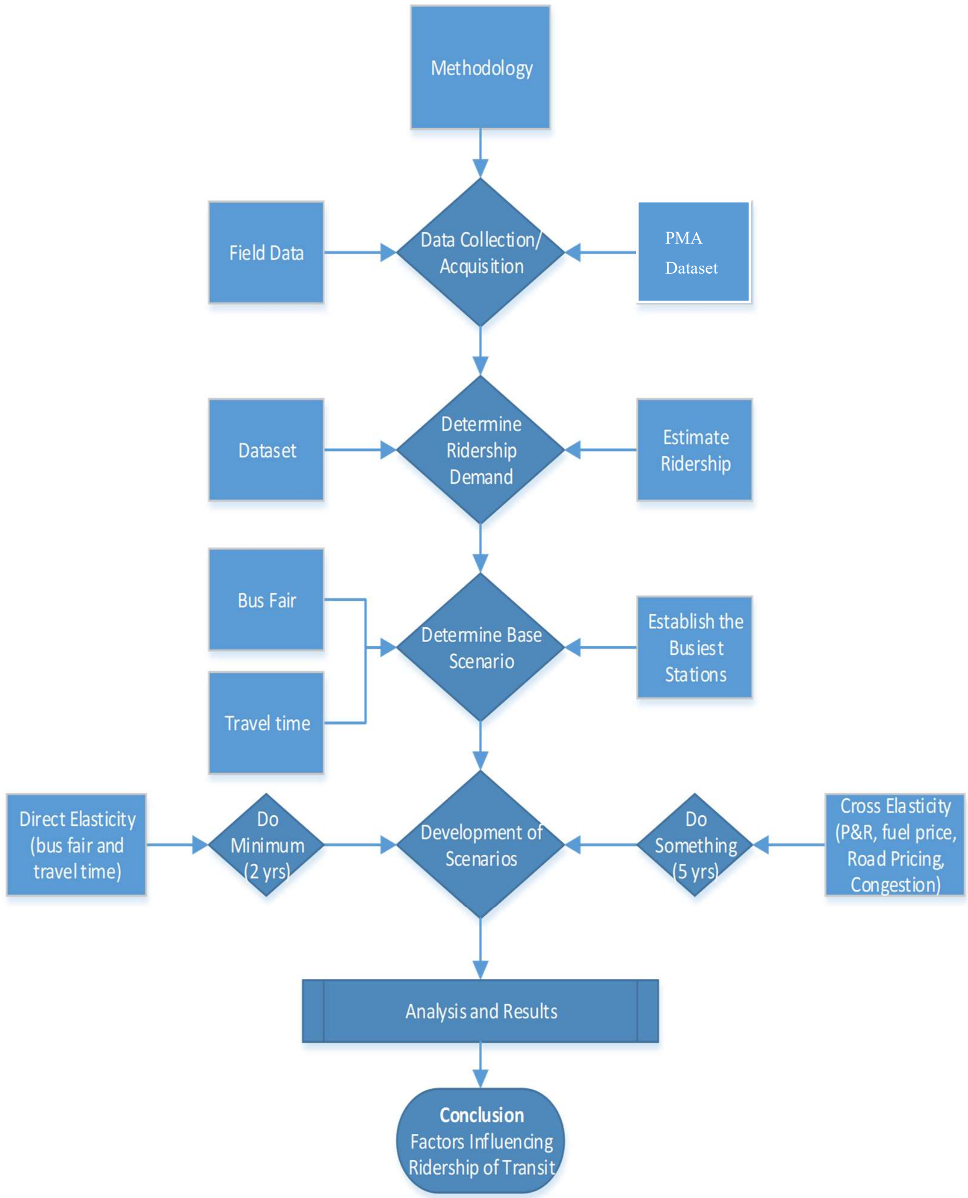


Figure 2: Study Framework

This work focuses mainly on obtaining of the demands for the Metro Bus in the light of various factors like travel time, fare change Pandemic etc., for the coming 2 years and 5 years periods. This research work involves following stages:

1. The process starts with selecting the study area and scoping the information that provides an overview of the transit users in the study area.
2. The second stage involves data collection and variable extraction. By referring the related research work, websites, and PMA (Punjab Masstransit Authority) for the required data.
3. In third stage, we determined the ridership demand using the acquired data sets related to ridership.
4. In the fourth stage, we generated the base scenario out of the data, for the busiest stations, based on the factors of travel time and bus fare. The busiest stations turned out to be these 3 Saddar, Committee Chowk and Faizabad.
5. The fifth stage of the process involves the exploration of the relation between different variable and their effects on the demand of the transit ridership in the following 2 and 5 years by developing Do minimum (DM) and Do something (DS) scenarios.
6. In the sixth stage, we analyzed the effects of the variables on the ridership and stated our conclusion.

In our analysis, we made different cases/scenarios of what would happen if we made following changes to the metro system in the coming years. By reducing the travel time which is kept constant since the metro started or by increasing the fare in peak or off-peak hours.

Introducing the concept of peak and off-peak hours in the metro system to make it more efficient and less fragile towards the dropping ridership in the off-peak hours. So, the following cases are discussed separately below.

## 3.1 Data Collection

### 3.1.1 Meeting with Authorities

We had our first meeting with Punjab Masstransit Authority (PMA) in October 2020. We have discussed with them about our initial views and understandings about our Final Year Project. They have provided the required data related to ridership. At first, we have performed data screening and sorting out into year, month, fair and hourly basis. Our calculations are based in the sub-division of dataset as mentioned in the framework. Based on the dataset, we have used models, from the literature review, to predict the outcome of ridership under different circumstances.

## 3.2 Travel Time

The average travel time between the stations was manually noted by exclusive travel in the metro bus between the three selected stations that had the maximum Alighting or Boarding ridership. The travel time between the station was almost fixed and it showed little variation depending on the distance between the adjacent stations. However, the time that we have observed coincides with timetable schedule. In the methodology framework, we have a study scenario of running a dedicated bus service for the peak hours at busiest three stations. Therefore, we altered the time by subtracting the stopping time of bus at non-busy stations. Thus, we have the value of travel time of covering busiest stations at peak hours.

## 3.3 Transit Demand Formula

We have used the following equation of transit demand for Do Minimum (DM) scenarios:

Equation 1: Calculation of Transit Demand using Direct Elasticity Method

$$V_{OD} = T^{-0.23} * P_{peak}^{-0.23} * P_{off\text{-}peak}^{-0.42}$$

where

| | |
|---|---|
| V | transit ridership/hr between origin and destination |
| T | transit travel time (hrs) |
| P | transit fare ($) |
| A | cost of auto trip ($) |
| I | average income ($) |

The data that was needed to carry out the required calculation for the transit demand for the two years scenarios was Ridership, Travel time (obtained by exclusively travelling in the Metro bus), Bus fare.

However, for Do-Something Scenario (5 years policy initiatives impact), we have used the following equation.

Equation 2: Calculation of Transit Demand using Cross Elasticity Method

$$V = P^{-0.32} * FP^{0.162} * RP\&C^{0.18} * P\&R^{0.363}$$

where

V transit ridership/hr between origin and destination.

P transit Fare ($)

FP fuel price ($)

RP&C road pricing and congestion ($)

P&R park and ride ($)

## 3.4 Scenarios

### 3.4.1 Analyses of Present Situation

We did the present analysis of the effect of fare change that occurred in August 2019 and compared that ridership data with August 2018. It will assist in determining whether the ridership would be increased or decreased by that fare change or did it have no effect whatsoever.

Similarly, we analyzed the pandemic that occurred in years 2020. To see how it affected the ridership and what if this pandemic continues for the next two years, and how much it effects on transit ridership.

To see if these changes, we have considered 2019 as a bae year. We have developed four future scenarios/ cases using various factors either individually or combined, to check the demand of the metro bus for the next 2 years as named as Do Minimum. However, to assess an impact of the fare change we consider the based year as same as 2019 and compare values of the particular month August, wherein fair has increased from R. 20 to R.30, with of the previous year 2018.

In these cases, we checked the behavior using direct elasticities method. The Cases are as follows:

### 3.4.2 DM (1) – Fare Based Impact

In the first case of do minimum, we increase the fare of the peak hours while keeping every other factor constant. The fare in this case has increased from 30 to 40 rupees, depending on the fare increase trend from the last 5 years.

To calculate the transit demand for the case, we used the above (Equation 1).

Ridership of the year 2019 was taken as the base model for this model and the future ridership for this model was determined by using the population growth factor that is 1.96 (Population growth factor of 1.96 was taken) (World Population Review). In the case of DM1, the change in price of ticket is that ticket prices for the passengers at peak hours is raised from Rs. 30 to 40, but the ticket price at non-peak hours is kept the same at Rs. 30.

### 3.4.3 DM (2) – Travel Time Based Impact

In this model, the fare is kept constant for both peak and off-peak hours while an additional bus is running only for peak hours, to reduce the travel time in this case, which will only go through busy stations of metro Rawalpindi that are:

- Saddar
- Committee Chowk
- Faizabad

Ridership of year 2019 was taken as a base value and the next 2 years ridership was predicted (Population growth factor of 1.96 was taken). The fare has kept constant at 30 rupees. This case was taken to analyze the effect of travel time during peak hours. The travel time which is constant in metro is being reduced in the three stations which are (Saddar, Committee Chowk & Faizabad). An additional bus will run from Saddar to Faizabad during peak hours to cater overloading of buses and to check whether the phenomena will increase the ridership or not. It will stop only on these 3 stations which have the highest ridership within Rawalpindi.

To calculate demand for this model, we used the same formula (Equation 1) as above.

### 3.4.4 DM (1+2) - Travel time and fare-based impact

In this model, the price of metro ticket has increased for both peak and off-peak hours from 30 to 40 rupees, along with addition of a bus to the route during the peak hours to cater for the overloading of the buses and to reduce travel time between these stations.

To calculate the transit demand for this model, we used the above Equation 1.

### 3.4.5 DM′ - Travel time impact along with increase bus fare in only peak hours

After DM (1+2) we predicted a case named DM′ for our analysis. In this case, the travel time between the peak stations of Rawalpindi was reduced as mentioned above. It is running an extra bus connecting 3 stations and the fare was increased for only peak hours from 30 to 40 rupees. While the fare for the off-peak hours remained the same as of now that is 30 rupees.

To calculate the transit demand for this model, we used the equation noted as Equation 1.

### 3.4.6 DS

For long term impact analysis, we considered the cross-impact factors. These cross-impact factors are Bus Fare, Fuel Price, Road Pricing & Congestion, Park n Ride. The object is to consider these factors and assess the policy-based initiation by the government agencies to see the impact on the ridership.

How different factors will affect the ridership of metro. It is neither dependent on travel time or fare increase like the previous ones and nor on the peak and off-peak hours. Values of these factors were assumed from the general trend continuous from the last 5 years or were taken by doing survey. While However, for Do-Something Scenario (5 years policy initiatives impact), we have used the following equation.

Equation 2 was used for the calculation.

By considering these factors we will see whether these factors will increase the ridership that we assumed to be in next 5 years by considering 2019 as base value and applying a growth factor upon them or whether these factors tend to reduce the ridership value than that.

# CHAPTER 4

## ANALYSIS AND RESULTS

### 4.1 Effect of Pandemic on Current Ridership

We ran our analysis on the existing data of year 2019 and 2020. Our existing data revealed results that are explained in the Figure 3 given below.

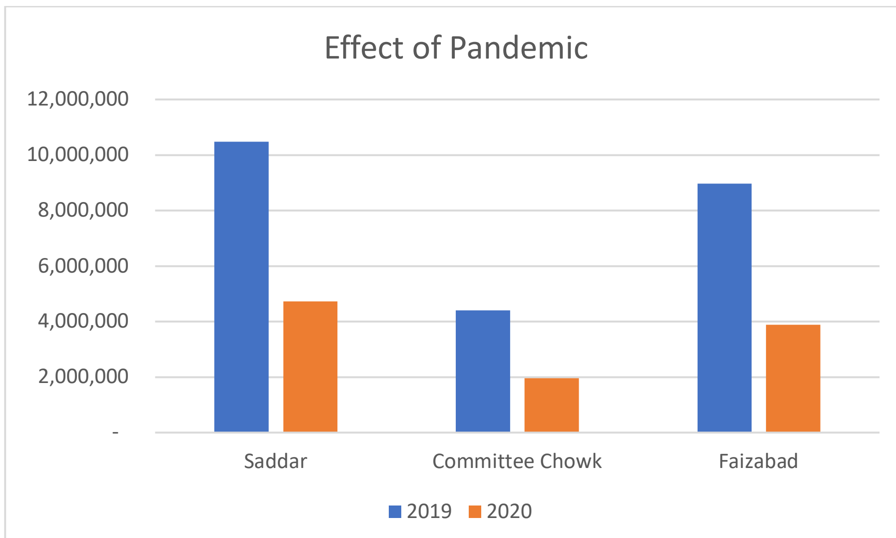


Figure 3: Effect of Pandemic on Ridership (passengers/hr)

The results show a drastic decrease in the ridership of metro during the current pandemic. It is also mainly due to metro was shut down because of covid-19 from April-2020 to August-2020. The ridership was decreased to 55%, 56% and 57% on Saddar, Committee Chowk, and Faizabad station, respectively.

### 4.2 Effect of Fare Change In 2019

We ran our analysis on the existing data of August 2019 when fare was increased, and compared it with the data of August 2018. Because of the unavailability of the data, the comparison cannot be done for the whole year of 2018 and 2019. Thus, we compared the 2 months and analyzed the impact of fare increase on the ridership. Our analysis revealed following results.

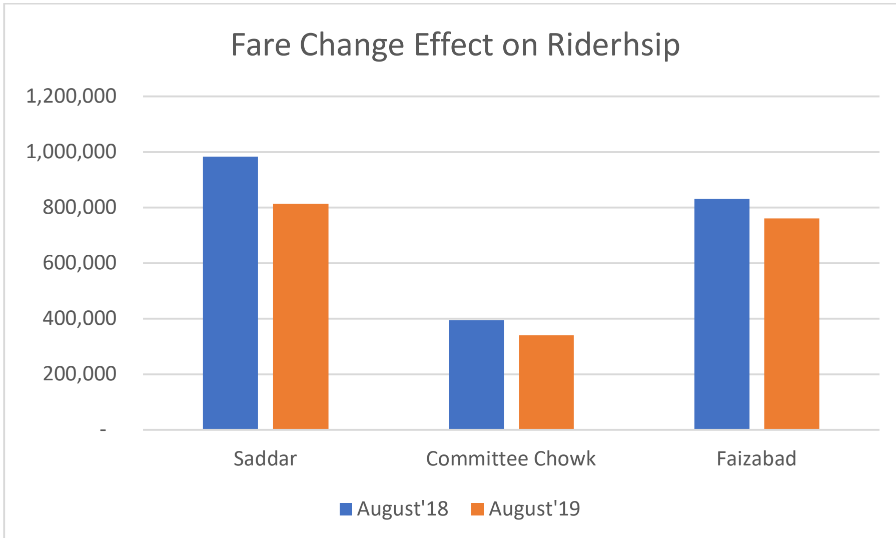


Figure 4: Effect of Fare Change on Ridership (passengers/hr)

From the Figure 4, we can see that ridership was decreased 17%, 14% & 8% on Saddar, Committee Chowk, and Faizabad, respectively. We further analyzed if the increase in the fare of metro increased the revenue (generated by tickets) as well. The results of that analysis are shown below.

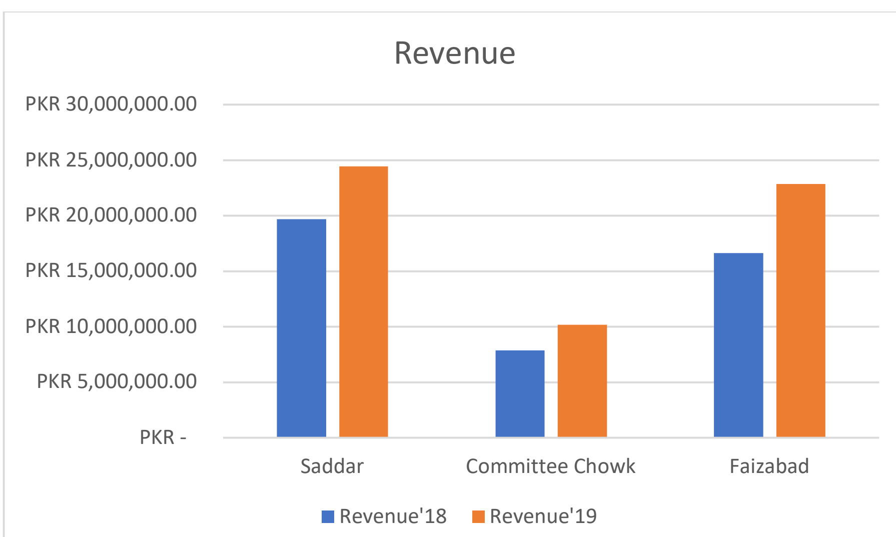


Figure 5: Comparison of Revenue between 2018 and 2019

The above Figure 5 shows that the revenue has increased not because of the increase in the ridership but resulted from an increase in fare from Rs. 20 to 30. Hence, showing that the fare increased resulted in PMA's favor.

### 4.3 DM (1)

In our first case of Do-Minimum, the ridership of year 2019 has been used as a base case. Its ridership is given below in passengers per hour.

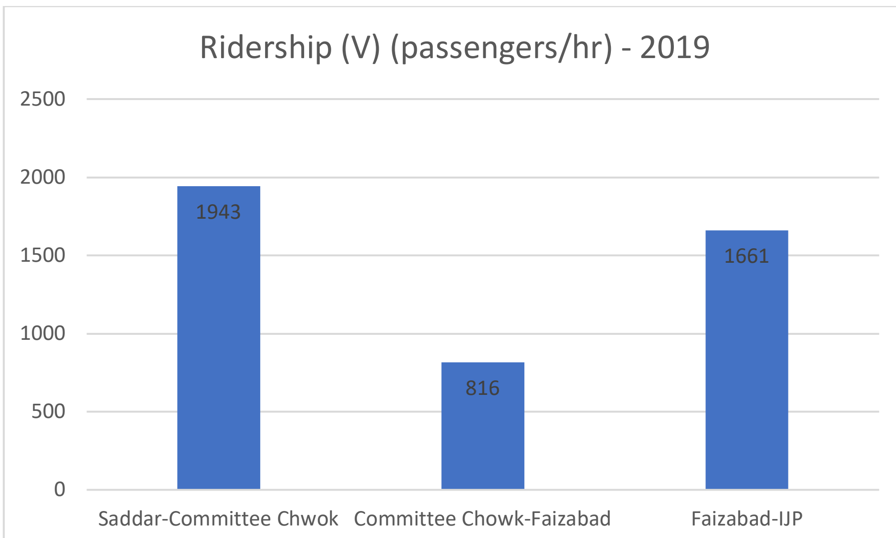


Figure 6: Ridership (passengers/hr) – 2019 for DM [1]

The Figure 7 shows the demand impact values of top 3 peak stations of metro Rawalpindi in the next 2 years for peak and off-peak hours.

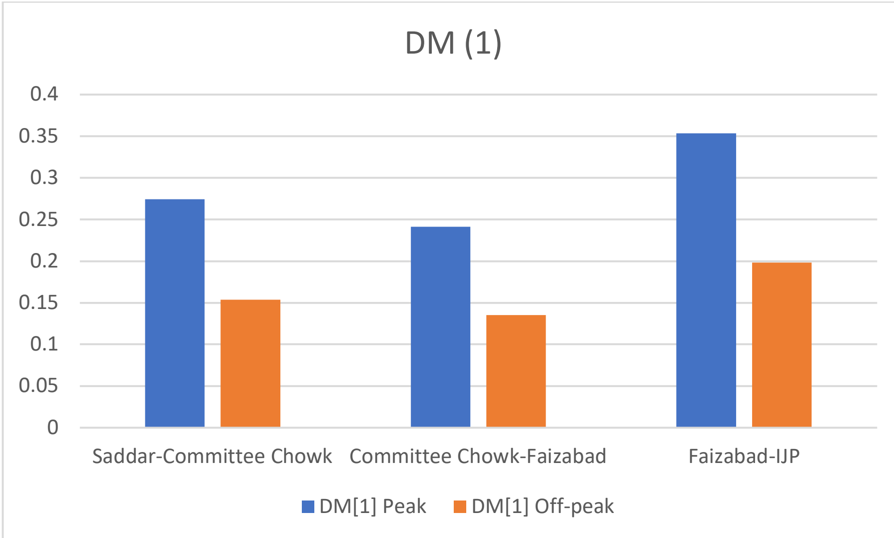


Figure 7: Demand Impact Values for DM [1]

The demand of next 2 years has predicted by using these demand impact values, and elasticity values as given in above Equation 1. The demand for 3 peak stations is given below.

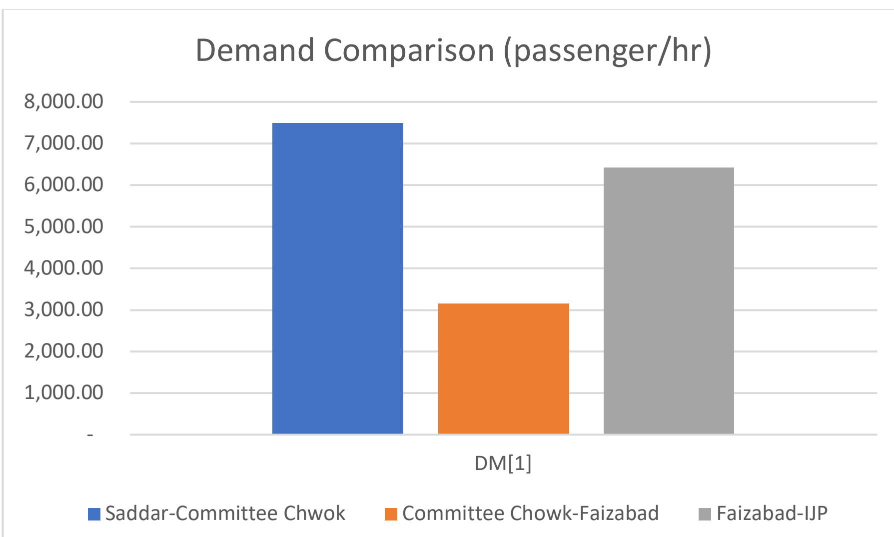


Figure 8: Demand Comparison (passengers/hr) between peak 3 stations (DM 1)

### 4.4 DM (2)

In the second case of Do-Minimum, an additional bus will decrease the travel time between the peak 3 stations of metro Rawalpindi. The travel time in minutes is shown below in Figure 9.

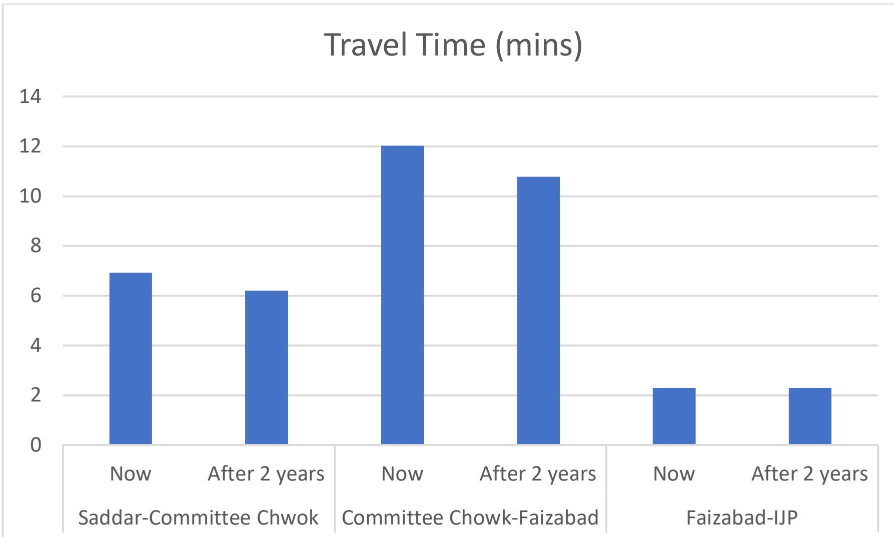


Figure 9: Travel Time (mins) for DM (2)

The demand impact values of the 3 peak stations are generated using Equation 1. These values are then compared with the demand impact values of the previous case that is DM (1). It is illustrated in the figure shown below.

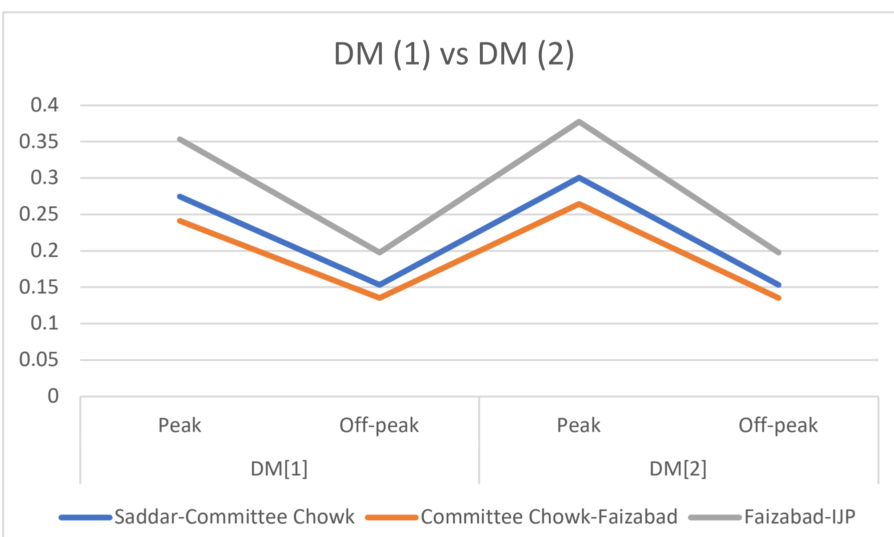

Figure 10: Comparison between Demand Impact Values for 2 Cases (DM [1] and DM [2])

As shown in the Figure 10, there is an increase in the demand impact values of DM (2) of all 3 stations during the peak hours compared to DM (1). This shows that passengers are more attracted towards the metro if the travel time between the 3 peak stations of Rawalpindi is decreased during the peak hours by running an additional bus and while the fare is kept constant to Rs 30. There is not much increase or decrease in the demand impact value of off-peak hours.

## 4.5 DM (1+2)

We have increased the fare by 33.33% in both peak and off-peak hours. The demand impact value for this case has generated using Equation 1. The pattern of demand impact values is shown below in the figure.

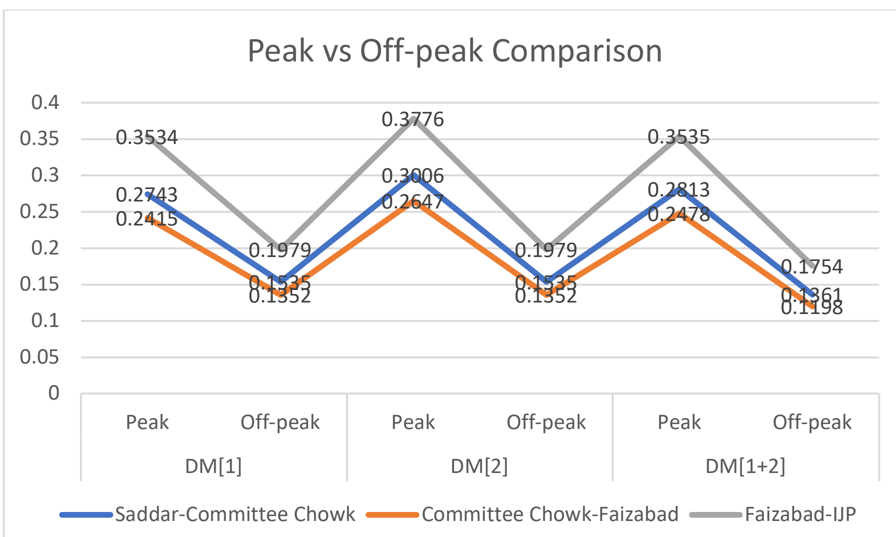


Figure 11: Comparison between Demand Impact Values of 3 Cases (DM [1], DM [2] and DM [1+2])

The Figure 11 illustrates that the demand impact value did not show much variation during the peak hours, but it dropped considerably during the off-peak hours showing that the passengers of off-peak hours either shifted to the peak hours or preferred some other mode of transportation for their travel. Thus, if we increase the fare in both peak and off-peak hours it will affect the demand impact value in a negative way. The ridership will decrease whether we run an additional bus to decrease the travel time between the busiest stations of Rawalpindi.

## 4.6 DM′

In this case, the travel time between the peak stations of Rawalpindi was reduced as mentioned above in DM (2) by running an extra bus among 3 peak stations. The fare was also increased for only peak hours from Rs 30 to 40 while the fare for the off-peak hours remained the same as of now that is Rs 30. The Equation 1 was used to generate the demand impact values. The demand impact values has shown below in Figure 12 and compared with the previous Do-Minimum cases.

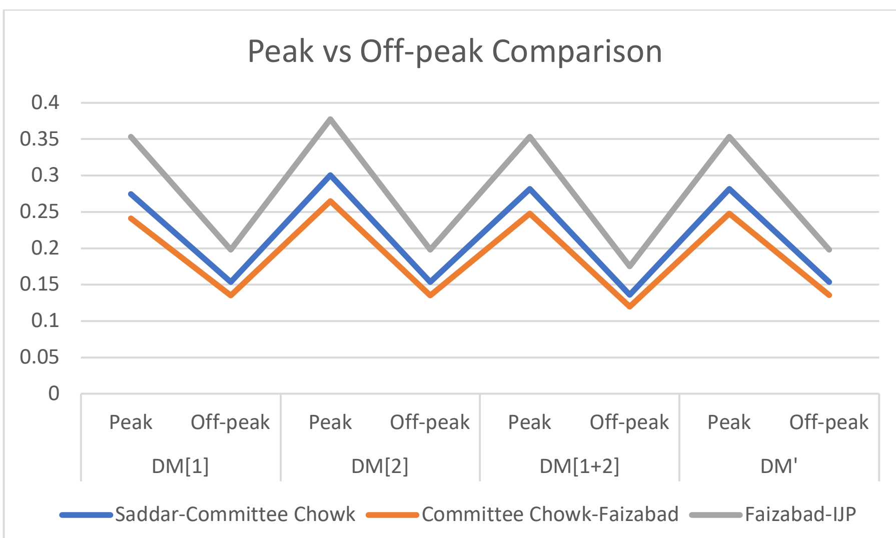


Figure 12: Comparison between Demand Impact Values of 4 Cases (DM [1], DM [2], DM [1+2] and DM′)

It shows no such change in the demand impact value for peak hours, but it shows a considerable uplift in the demand impact value of off-peak hours. It means that people still preferred metro more in the off-peak hours when the fare was kept constant at Rs. 30 while the peak hour pattern was same as for the previous case that is DM (1+2) for all the 3 stations under study.

The below Table 1 shows the comparison between the ridership after 2 years with only growth factor applied without increasing the fare of the metro with the above discussed cases that is DM (1), DM (2), DM (1+2) & DM′.

Table 1: Comparison between Demand in 2021, DM [1], DM [2], DM [1+2] and DM′

| S/No. | Station Name | Demand in 2021 | DM (1) | DM (2) | DM (1+2) | DM′ |
|---|---|---|---|---|---|---|
| 1. | Saddar-Committee Chowk | 7464.23 | 7,489.91 | 7491.48 | 7489.28 | 7490.33 |
| 2. | Committee Chowk – Faizabad | 3134.75 | 3,157.36 | 3158.74 | 3156.80 | 3157.73 |
| 3. | Faizabad - IJP | 6380.90 | 6,413.98 | 6415.43 | 6412.63 | 6413.98 |

The ridership value has compared with the demand in 2021 (which was generated using 2019 ridership value as a base value), DM (1), DM (2), DM (1+2) and DM′. We have observed that the demand values of all the Do-Minimum cases were greater than that of Demand in 2021. The highest demand value was generated by DM (2) followed by DM′ and DM (1).

## 4.7 DS (5-year Plan)

We have considered the policy-based initiatives, as explained in the methodology, by comparing their demand with the demand in year 2025 (generated by using ridership of 2019 as base amount). The demand of DS (Do-Something) has generated by using the However, for Do-Something Scenario (5 years policy initiatives impact), we have used the following equation.

Equation 2.

Table 2: Comparison between Demand in 2025 and DS

| S/no. | Station Name | Demand in 2025 | DS |
|---|---|---|---|
| 1. | Saddar-Committee Chowk | 56202.18 | 56511.49 |
| 2. | Committee Chowk – Faizabad | 23603.18 | 23912.49 |
| 3. | Faizabad - IJP | 48045.20 | 48354.51 |

Saddar-Committee Chowk ridership was increased from 56202 to 56511. Committee Chowk-Faizabad ridership was increased from 23603 to 23912. Faizabad-IJP ridership was increased from 48045 to 48354. We can say that due to these factors the demand was increased, and passengers opted for metro more. Population of central city increase; Service and Income were not considered in this case.

# CHAPTER 5

## CONCLUSION

First, we have analyzed the effect of pandemic wherein found that the ridership decreased due to COVID as metro was completely shut down for some months. Effect of fare increase in August 2019 shows a decrease in ridership value compared to August 2018, but the revenue generated during the same time is increased merely due to change in bus fare. Secondly, we have observed an increase in ridership resulted from an increase in the fare change for peak hours. The increase trend in ridership is observed by reducing the travel time at busiest stations. However, that increase is of great marginal value as compared to the fare change and it is justifiable. However, we have simultaneously applied increase in bus fare and travel time reduction has resulted in increase in the ridership but less than the previous case. This indicates about people acceptance to the policy change is much in favor by adopting in segregated approaches rather than apply them in combined manner. Moreover, increase fair along with decrease travel time for peak time only without disturbing off-peak hours has resulted in increase in the ridership but less popular to users' point of view as of the just focusing on the reduced travel time approach. Our results also supported an increase in the ridership would be expected from other urban transportation schemes (i.e. park and ride, road pricing and congestion zones), and further measures (like escalation in petrol pricing, area population). However, these are subject to facilities available to transit service of premium quality or at-least equivalent to private mode, is the way to shift private mode users to public mode-based journey tips.

# LIMITATIONS

The available dataset to conduct this study is of two years. However, for such a study of this nature requires at least five years of dataset.

We have used the elasticity values based on different cities around the world. Moreover, it is justifiable for the meso-level planning study because the generic behavior of the people. However, there is need to conduct a separate study for model development. It is said so because the people perception changes with the geographic and income values. Additionally, there is a vast critical thinking approach difference in users belong to the developed to the developing nation. Therefore, we are highly recommended a detailed study for national, provisional, and local development authority level.

Our study did not cover bus capacity in line with the ridership, as it is out of our scope. Therefore, it is advisable to include bus capacity and enhancement schemes that will be required in future year with detailed economic efficiency impact analysis, incorporating income, CBD population, and inflation.

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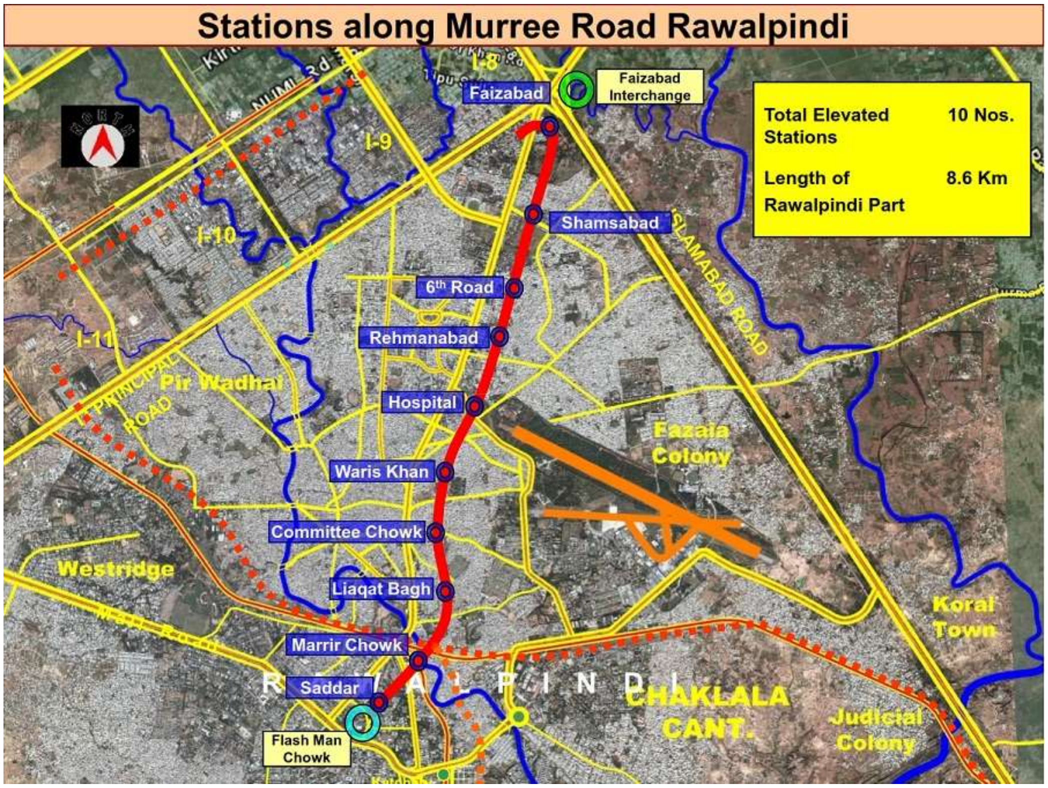
# Appendix

## Appendix A - Maps


(Source: https://www.zameen.com/blog/metro-bus-islamabad.html)

The above map displays Line 1 of the Rawalpindi-Islamabad Metrobus which initiates from Saddar Station, Rawalpindi and ends on Pak secretariat Station, Islamabad. There are a total of 24 stations in this Line with 11 stations from Saddar Station, Rawalpindi to IJP Station, Rawalpindi being involved in our study.




(Source: https://www.facebook.com/metroislamabadrawalpindi/)

The above image shows 10 out of the 11 stations involved in our study. Excluding IJP Station, all the stations in our study are situated on Murree Road, Rawalpindi so this image shows the placement and relevant distance between each station with each other.

## Appendix B – PMA Dataset

| Monthly Variation in Boarding (2019) | | | |
|---|---|---|---|
| STATION | Saddar | Committee Chowk | Faizabad |
| January-19 | 534,347 | 239,254 | 430,619 |
| February-19 | 462,430 | 205,753 | 378,453 |
| March-19 | 518,557 | 228,987 | 439,913 |
| April-19 | 494,288 | 215,938 | 436,185 |
| May-19 | 372,342 | 160,808 | 328,806 |
| June-19 | 383,939 | 159,108 | 389,486 |
| July-19 | 476,349 | 191,947 | 434,277 |
| August-19 | 392,773 | 164,769 | 379,070 |
| September-19 | 404,752 | 156,725 | 355,601 |
| October-19 | 412,460 | 162,652 | 349,444 |
| November-19 | 240,821 | 99,983 | 201,901 |
| December-19 | 387,792 | 158,596 | 339,785 |
| TOTAL | 5,080,850 | 2,144,520 | 4,463,540 |

| Monthly Variation in Alighting (2019) | | | |
|---|---|---|---|
| STATION | Saddar | Committee Chowk | Faizabad |
| January-19 | 563,645 | 249,835 | 440,235 |
| February-19 | 487,421 | 214,003 | 389,200 |
| March-19 | 543,289 | 239,863 | 450,214 |
| April-19 | 525,127 | 230,233 | 444,141 |
| May-19 | 385,561 | 167,283 | 315,588 |
| June-19 | 425,589 | 168,148 | 384,956 |
| July-19 | 508,735 | 205,214 | 439,035 |
| August-19 | 421,754 | 174,330 | 382,516 |
| September-19 | 429,951 | 166,075 | 359,441 |
| October-19 | 438,761 | 170,897 | 358,982 |
| November-19 | 261,406 | 106,001 | 205,129 |
| December-19 | 416,066 | 168,514 | 335,909 |
| TOTAL | 5,407,305 | 2,260,396 | 4,505,346 |

| Monthly Variation in Boarding (2020) | | | |
|---|---|---|---|
| STATION | Saddar | Committee Chowk | Faizabad |
| January-19 | 473,991 | 136,716 | 395,639 |
| February-19 | 400,124 | 116,928 | 348,892 |
| March-19 | 278,549 | 79,643 | 240,391 |
| April-19 | 0 | 0 | 0 |
| May-19 | 0 | 0 | 0 |
| June-19 | 0 | 0 | 0 |
| July-19 | 0 | 0 | 0 |
| August-19 | 125,306 | 30,635 | 114,421 |
| September-19 | 284,294 | 68,587 | 245,454 |
| October-19 | 300,610 | 79,764 | 236,772 |
| November-19 | 254,313 | 68,145 | 192,937 |
| December-19 | 173,567 | 44,501 | 150,240 |
| TOTAL | 2,290,754 | 624,919 | 1,924,746 |

| Monthly Variation in Alighting (2020) | | | |
|---|---|---|---|
| STATION | Saddar | Committee Chowk | Faizabad |
| January-19 | 504,639 | 206,140 | 405,591 |
| February-19 | 427,357 | 175,640 | 354,976 |
| March-19 | 295,111 | 118,851 | 251,754 |
| April-19 | 0 | 0 | 0 |
| May-19 | 0 | 0 | 0 |
| June-19 | 0 | 0 | 0 |
| July-19 | 0 | 0 | 0 |
| August-19 | 133,449 | 53,342 | 107,424 |
| September-19 | 300,507 | 118,804 | 247,826 |
| October-19 | 318,141 | 131,019 | 240,616 |
| November-19 | 270,753 | 111,485 | 197,329 |
| December-19 | 186,056 | 78,640 | 152,353 |
| TOTAL | 2,436,013 | 993,921 | 1,957,869 |

## Appendix C – Performance Evaluation Tables

| Current Situation DN (Ridership data) 2018 | Saddar-Committee Chowk | Committee Chowk-Faizabad | Faizabad-IJP |
|---|---|---|---|
| Travel Time (TT) mins | 6.92 | 12.03 | 2.3 |
| Demand (V) (passengers/hr) | 876 | 361 | 719 |

| 2019 (fare change) | Saddar-Committee Chowk | Committee Chowk-Faizabad | Faizabad-IJP |
|---|---|---|---|
| Travel Time (TT) mins | 6.92 | 12.03 | 2.3 |
| Demand (V) (passengers/hr) | 1943 | 816 | 1661 |

| 2020 (COVID/Pandemic) | Saddar-Committee Chowk | Committee Chowk-Faizabad | Faizabad-IJP |
|---|---|---|---|
| Travel Time (TT) mins | 6.92 | 12.03 | 2.3 |
| Demand (V) (passengers/hr) | 876 | 361 | 719 |

| Do-minimum DM [1] (TT constant - 2 years) | Saddar-Committee Chowk | Committee Chowk-Faizabad | Faizabad-IJP |
|---|---|---|---|
| Ridership Growth Value (passengers/hr) | 7,464.23 | 3,134.75 | 6,380.90 |
| Travel Time (TT) mins | 6.92 | 12.03 | 2.3 |
| Bus Fare (TC) for peak time (Rs.) | 40 | 40 | 40 |
| Bus Fare (TC) for Off-peak time (Rs.) | 30 | 30 | 30 |
| Demand (V) for Peak time (passengers/min) | 0.2743 | 0.2416 | 0.3535 |
| Demand (V) for Off-Peak time (passengers/min) | 0.1536 | 0.1353 | 0.1979 |
| **Total Ridership (passengers/hr)** | **7,489.91** | **3,157.36** | **6,413.98** |

| **Do-minimum DM [2] (TT varies - 2 years)** | **Saddar-Committee Chowk** | **Committee Chowk-Faizabad** | **Faizabad-IJP** |
|---|---|---|---|
| Ridership Growth Value (passengers/hr) | 7464.229 | 3134.746 | 6380.898 |
| Travel Time (TT) Peak mins | 6.2 | 10.78 | 2.3 |
| Bus Fare (TC) for peak time (Rs.) | 30 | 30 | 30 |
| Bus Fare (TC) for Off-peak time (Rs.) | 30 | 30 | 30 |
| Demand (V) for Peak time (passengers/min) | 0.3006 | 0.2647 | 0.3776 |
| Demand (V) for Off-Peak time (passengers/min) | 0.1536 | 0.1353 | 0.1979 |
| **Total Ridership (passengers/hr)** | **7,491.48** | **3,158.74** | **6,415.43** |

| **Do-minimum DM [1+2] (TT varies - 2 years)** | **Saddar-Committee Chowk** | **Committee Chowk-Faizabad** | **Faizabad-IJP** |
|---|---|---|---|
| Ridership Growth Value (passengers/hr) | 7464.229 | 3134.746 | 6380.898 |
| Travel Time (TT) Peak mins | 6.2 | 10.78 | 2.3 |
| Bus Fare (TC) for peak time (Rs.) | 40 | 40 | 40 |
| Bus Fare (TC) for Off-peak time (Rs.) | 40 | 40 | 40 |
| Demand (V) for Peak time (passengers/min) | 0.2814 | 0.2478 | 0.3535 |
| Demand (V) for Off-Peak time (passengers/min) | 0.1361 | 0.1199 | 0.1754 |
| **Total Ridership (passengers/hr)** | **7,489.28** | **3,156.80** | **6,412.63** |

| **Do minimum DM′ (TT varies - 2 years)** | **Saddar-Committee Chowk** | **Committee Chowk-Faizabad** | **Faizabad-IJP** |
|---|---|---|---|
| Ridership Growth Value (passengers/hr) | 7464.229 | 3134.746 | 6380.898 |
| Travel Time (TT) Peak mins | 6.2 | 10.78 | 2.3 |
| Bus Fare (TC) for peak time (Rs.) | 40 | 40 | 40 |
| Bus Fare (TC) for Off-peak time (Rs.) | 30 | 30 | 30 |
| Demand (V) for Peak time (passengers/min) | 0.2814 | 0.2478 | 0.3535 |
| Demand (V) for Off-Peak time (passengers/min) | 0.1536 | 0.1353 | 0.1979 |
| **Total Ridership (passengers/hr)** | **7,490.33** | **3,157.73** | **6,413.98** |

| **Do-Something DS (5-year plan)** | **Saddar-Committee Chowk** | **Committee Chowk-Faizabad** | **Faizabad-IJP** |
|---|---|---|---|
| Ridership Growth Value (passenger/hr) | 56,202.18 | 23,603.18 | 48,045.20 |
| Bus Fare (TC) (Rs.) | 60 | | |
| Fuel Price (FP) (Rs.) | 156.3 | | |
| Road Pricing & Congestion (RP&C) (Rs.) | 40 | | |
| Park and Ride (P&R) | 60 | | |
| Demand (passengers/min) | 5.155162466 | | |
| **Total Ridership (passengers/hr)** | **56,511.49** | **23,912.49** | **48,354.51** |