TRAFFIC IMPACT ANALYSIS OF NEW-RESIDENTIAL SCHEMES IN THE VICINITY OF ISLAMABAD AIRPORT OVER MAJOR INTERSECTIONS OF N-5

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Department of Transportation Engineering

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Islamabad, Pakistan

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A thesis submitted to the in partial fulfilment of the requirements for the degree

of

Master of Science

in

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Thesis Supervisor: Dr. Sameer-ud-Din (P.E.)

Department of Transportation Engineering

School of Civil and Environmental Engineering

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THESIS ACCEPTANCE CERTIFICATE

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Signature (HOD): ______________________________

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I, Hamza Haroon Khan hereby state that my MS thesis titled "Traffic Impact Analysis of New-Residential Schemes in Vicinity of Islamabad Airport over Major Intersections of N-5" is my work and has not been submitted previously by me for taking any degree from the National University of Sciences and Technology, Islamabad or anywhere else in the country/ world.

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ACKNOWLEDGEMENTS

In the name of Almighty ALLAH, the most Merciful, the Beneficent. All praise is only for ALLAH, our Creator, who always planned the best for us. I am grateful to Almighty ALLAH for His countless blessings and mercy bestowed upon me through the difficulties of life and I seek His guidance and pray to Him for blessings and ease throughout this life and the life to come.

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(***Hamza Haroon Khan***)

ABSTRACT

A traffic impact analysis is a method to evaluate whether the transportation infrastructure is enough now or in the future to handle more trips brought on by a proposed construction, redevelopment, or land rezoning. In this study, the impact of current traffic volume and traffic volume being generated by new housing societies on the existing road network concerning development years is analyzed. The analysis is done on the road network with do-nothing, do-minimum and do-something scenarios. The analysis is based upon some parameters: travel time, the value of travel time and vehicle operating cost. For the calculation of these parameters, the HCM method, HDM-4 Model used in NTRC Study, Hepburn Model and Synchro software are used. Traffic Impact is analyzed as a difference in monetary terms of these parameters due to differences in traffic volume due to different years of development, increase or decrease in travel time and variation in vehicle operating cost as well as due to different scenarios development.

Keywords: Vehicle operating Cost, Travel Time, Value of Travel time, Level of Service, scenarios development

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CHAPTER 1: INTRODUCTION

A traffic impact analysis is a method to evaluate whether the transportation infrastructure is enough now or in the future to handle more trips brought on by a proposed construction, redevelopment, or land rezoning. As, new developments generate additional trips on existing road networks which cause congestion, stop-and-go situations at both links and nodes, delays at links and nodes, an increase in air pollution, road accidents, and many more problems. To solve all these problems in time and within budget constraints, as a tool for planning, traffic impact assessments are more frequently used to predict demands on the transportation network. Based on the nature, scale, and location of the development, different traffic impact studies are required.

Given the foregoing, TIA is required for any area where development, redevelopment, or land rezoning are being considered. One of the regions in Pakistan where there is a necessity for this study because of the development of non-developed sectors and other housing societies due to population increase is Islamabad.

The capital and ninth-largest city of Pakistan is Islamabad. With a population of around 3.1 million, the greater Islamabad Rawalpindi metropolitan region is the fourth largest in the nation. Islamabad is renowned for its excellent living conditions, safety, and lush surroundings. Due to their close social and economic relations, Rawalpindi and Islamabad, the capital of Pakistan, are collectively referred to as the "twin cities.". Rawalpindi is a major logistics and transportation center for northern Pakistan. Being the twin cities of Pakistan, these hold a lot of governmental and private offices, GHQ, business hubs, commercial plazas, religious places, hotels, and restaurants. These all-land uses attract a lot of traffic towards Islamabad and Rawalpindi which generate trips for different activities including work, education, shopping, healthcare, social, recreational, cultural, religious, political, etc. causing a lot of congestion on current road networks.

In recent years, traffic congestion had become a part of the daily commutes in the metropolitan cities of Pakistan. Traffic congestion can be observed on all major highways and internal roads during the peak hour in Islamabad city and in Rawalpindi as well. The traffic demand in Islamabad increased exponentially during the last few years due to several reasons which include an increase in population, migration of people from other cities, lack of proper public transport, and an increase in car ownership.

There will be more increase in population in near future due to the development of sectors, D, E, F, G, H, and I in Islamabad as mentioned above. Another major contributor to population increases and thus traffic volume will be the development of different housing societies in the vicinity of New Islamabad International Airport, motorway interchange (M-1) on N-5. These all developments will be responsible for the huge traffic influx in Islamabad and Rawalpindi in the future. To cater this fluctuation in Traffic Volume, a few necessary steps are required to be taken. Hence, Traffic Impact Study (TIS) is vital on current road networks to examine the impact of expected traffic.

1.1 Problem Statement

Currently, Srinagar Highway and N-5 are experiencing huge amounts of traffic. This traffic volume causes an increase in delays, travel time, travel cost, and an increase in VOCs the time passes by new developments in the form of new housing societies are being developed causing huge traffic flow into the metropolitan city, Islamabad. This huge amount of traffic will cause more delays, increased VOC, travel time, and travel cost.

1.2 Research Objectives

This study aims at finding the impact of newly generated traffic by doing a comparative analysis between different parameters. This study aims at achieving the following objectives:

a) To estimate the amount of traffic being generated by New Developments, and
b) To analyze the impact of New Developments' traffic load on major intersections of Srinagar Highway and Grand Trunk (GT) Road Rawalpindi.
c) Develop mitigation strategies to overcome the additional traffic influence from the new developments.

1.3 Study Area

Whenever an impact study is done, so first a study area is defined. The study area for this research starts in the near vicinity of New Islamabad International Airport, the area surrounding the M-1 Interchange, the area along the Srinagar Highway on both sides, and the area along N-5 including different housing societies. These all-housing societies are in the developing stage with some 30% developed and some 25% developed. These societies are officially registered with Rawalpindi Development Authority or Capital Development Authority, and these must get NOC either from RDA or CDA for further development. Their details are also uploaded on their respective websites.

The study area of this research starts from Faisal Hills in the West to Golra Mor in the East at N-5. In northing-southing it starts from the vicinity of the M-1 Motorway Interchange and ends at Islamabad Chowk/G-13 Chowk. There are almost 16 housing societies which come in our study area. These are Top City, Airport Green Garden, Gandhara City, Elite Reverie, Taj Residencia (Extension), Faisal Town, Pakistan Employees Co-operative Housing Society, Taj Residentia, Marble Arch Enclave, Faisal Hills, Khudadad City, Faisal Margalla City and Multi Gardens B-17. Some societies exist on the North, and some on the South of Srinagar Highway and GT Road N-5. The study area is shown in the following Figure 1-1 below.

1.4 Research /Controlled Points of Study Area

This study area consists of many links and nodes. Some links and nodes are critical in this study area while others are not. The main links in this study area are Srinagar Highway and GT Road N-5. Srinagar Highway is a major east-west highway in Islamabad which connects traffic from New Islamabad International Airport (NIIA) in the east to E-75 Expressway. The total length of this highway is 25 kilometres. In some places, its width is three lanes, and, in some places, it has five lanes. It has five interchanges.

GT Route N-5 is another important road that enters the area of our investigation. The N-5, also known as National Highway 5, is an 1819-kilometer national highway in Pakistan that connects Torkham in Khyber Pakhtunkhwa with Karachi in Sindh. Its region which comes in our study area extends from Faisal Hills housing society in the west to Golra Mor in the east. It is a highly congested and populated road portion.

Three main critical nodes that come in the study area are:

a) GT Road Rawalpindi 26 No Interchange,

b) Golra Interchange, and

c) Golra Mor.

The reason why these nodes are critical is the large volume of traffic that they hold daily. This volume of traffic is already coming from different cities, and it gets collected at these three intersections. All analysis will also be carried out on these three nodes. In fact, in the future as well, these nodes will collect the whole traffic volume of all housing societies in the study area as well as outside the study area. From these nodes traffic passes to other areas e.g., Murree, Kashmir, and the province of Punjab.

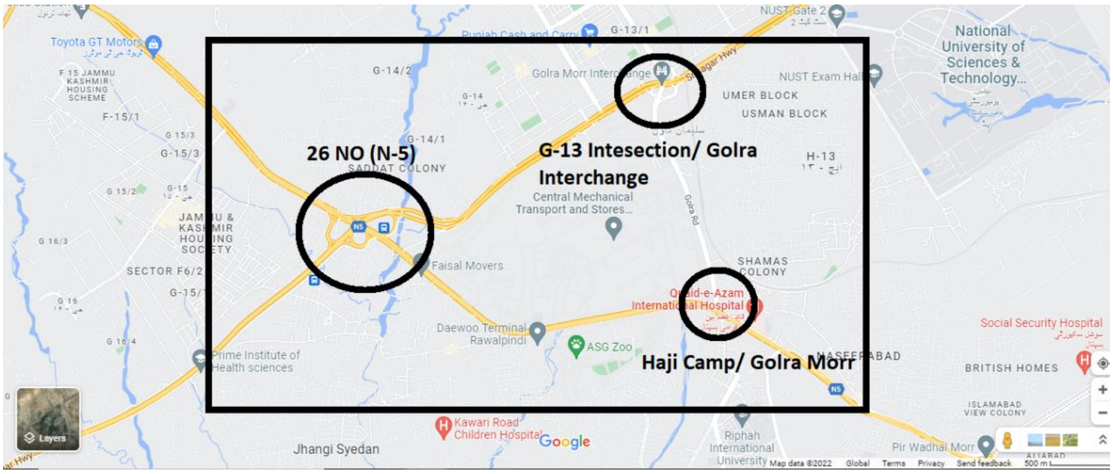

Figure 1-1: Study Area (Source: Google Maps dated 2022)

In this study area, there are currently two (2) road network links and three (3) intersections. The road network links are named the Srinagar (old Kashmir) Highway, and National Highway (N-5). However, the three (3) intersections that we have considered for this study are Islamabad (G-13/Golra Interchange) Chowk, 26 No Interchange at GT Road N-5 Rawalpindi, and Golra Morr (Haji Camp). The study zones are illustrated by drawing circles in Figure **1-1** above. Moreover, the details of the study zones showing their geometry, number of lanes, and intersection/interchanges types and features (e.g. ramp details, connecting links, etc.) are shown in Figure **1-2**, Figure **1-3**, and Figure **1-4** respectively.

Figure 1-2: Golra Interchange (Source: Google Maps dated 2022)

Figure 1-3: Rawalpindi GT Road 26 No Interchange (Source: Google Maps dated 2022)

Figure 1-4: Golra Mor (Source: Google Maps dated 2022)

CHAPTER 2: LITERATURE REVIEW

The traffic impact analysis (TIA) is a helpful tool for the early detection of prospective traffic problems and will be crucial in determining a workable solution. Based on the development's specifics, a TIA study evaluates the effect on the street network of a proposed development. This study offers suggestions for reducing the development's negative effects and improving the functionality of the nearby road network. [1] [2].

Additionally, failing to do a TIA research may result in an underestimation of the impact of development, which in turn may give rise to various issues. Lack of an appropriate TIA study has been linked to a number of negative outcomes, including an increase in conflicts, delays, reduced LOS on the roads, an increase in crash rates, poor traffic flow, an increase in congestion, unattractive strip development, pressure to signalize more locations, widening of an existing street, or construction of a bypass. [1].

Additionally, it is imperative to do a TIA study prior to development because it may identify numerous traffic-related issues that must be addressed right once [3]. In some cases, the flaws may be so serious that the project's design must be altered, or it may suggest a variety of improvements to lessen the impact of the extra traffic the proposed development will cause, such as the addition of traffic lanes, pedestrian walkways, the ability to make U-turns, changes to lighting, and so on. [4].

In past, many studies relating to TIA have been done. These studies can be classified as macroscopic and microscopic. To conduct these studies at different levels many methodologies are used. To determine mean trip rates for new developments, these techniques include applying the exponential growth model, trip rate analysis, cross classification approach, and regression analysis. Apart from the above-mentioned methods traffic estimation is also done with and without proposed development. The baseline transport data, public transport computation, road network valuation, traffic statistics and traffic projection, safety considerations and accident analysis, dedicated developments, and their projected traffic generation are the fundamental data required for large-scale traffic impact studies. [5], [6].

Their significance is amply demonstrated by a study comparing transportation impact assessments with transportation assessments. An examination of the road system and a travel survey were conducted to determine the daily trip rates and trip characteristics of the homes. People who use the site and work nearby were surveyed to gather information for a travel survey and to determine the trip characteristics of a road network questionnaire in order to learn more about the socioeconomic characteristics and features of everyday travel. The survey was useful for gathering information about the trip mode, trip purpose, trip time, and trip destination that is needed for travel analysis. [1].

To determine the mean trip rates for the site, a new development, the transportation impact assessment was completed using a variety of approaches, such as the exponential growth model, trip rate analysis, cross-classification method, and regression model. The fundamental information needed for a transportation assessment was gathered from a questionnaire survey and a travel survey, which included questions about the current site information, site use, traffic data, traffic conjecture, safety considerations, accident analysis, committed developments, and their likely traffic generation [7]. After the investigation, it was discovered that TIA's prediction of traffic volume with development completion only takes into account car trips.[1].

Another Traffic Impact Study was conducted on the traffic impact of the road passages due to the construction of the flyover at the Surabaya intersection in Banda Aceh, Indonesia. This study assesses and formulates the traffic impact caused by new construction zones to the surrounding road system and external road system, particularly the roads that form the main structure, and it offers solutions that can reduce traffic jams brought on by the new road construction. [10].

A traffic count study was conducted to gather information on traffic volume, noting all types of vehicles that passed the observation location every 15 minutes. Within an hour of the time period, this traffic volume had become traffic volume. During that hour, there was a variety of traffic, including motorcyclists, cars, 4WDs, minibuses, buses, and trucks. The number of cars was multiplied by the PCEs to create the Passenger Car Unit (PCU) from the vehicular traffic dataset. According to the research methodology, the impact study's defining characteristics were highway capacity, saturation level, and service level. The results of a traffic impact analysis were divided into two domains (macroscopic and microscopic level). Analyses are carried out at two different scales: microscopic and macroscopic. At the microscopic scale, the driver's conduct is examined individually.

As the primary factor in determining the level of service at intersections and segments, the degree of saturation (DS) is defined as the ratio of traffic volume to capacity. It was discovered by comparing a road's capacity and maximum volume [9]. Using the traffic manual IHCM, the capacity was calculated based on the physical characteristics of the road. The level of service (LOS) can be determined directly once the saturation level has been known. Highway geometrics, traffic volume, and spot speed for two days were the main data collected. The study site's map and secondary information on the amount of traffic at the Surabaya Intersection before construction were collected from earlier research. The conversion unit of passenger car equivalency (PCEs) for the urban street was used to convert traffic compositions into the uniform unit known as the passenger car unit (PCUs) for processing traffic volume [10].

Another recent study focused on Indonesia's practise of traffic effect assessment in order to highlight the significance of conducting a traffic impact analysis prior to new developments. Different traffic impact analysis models were compared, and the model that was most appropriate for Indonesia was chosen. [11].

Infrastructure traffic conditions, traffic counting, and analysing the efficiency of current traffic were the main data collection methods used in this study. Analysis of the current state of the research region, including the impact of the road network, intersections, and traffic conditions, was also conducted.

Performance assessment of current traffic data of traffic volume, speed, and density was done to find the level of service. A Traffic Counting survey was conducted to assess existing traffic conditions from the volume of vehicles per hour on these roads. Later, an assessment of data with and without development was also done [4].

One such case study that caught our attention was "Traffic Impact Assessment for Sustainable Development in Urban Areas." These results from two case studies—one involving an upcoming official complex in New Delhi's CBD and the other involving the expansion of an IT park in a special economic zone—are examined. The case examples emphasise the value of TIA and the necessity of making TIA a fundamental and obligatory requirement. [2].

One such case study that caught our attention was "Traffic Impact Assessment for Sustainable Development in Urban Areas." These results from two case studies—one involving an upcoming official complex in New Delhi's CBD and the other involving the expansion of an IT park in a special economic zone—are examined. The case examples emphasise the value of TIA and the necessity of making TIA a fundamental and obligatory requirement. [12].

The influence region was first identified, and then the number of trips that would be generated by the planned complex or corridor. The existing road network's traffic was included. Based on growth rates, the traffic for the horizon year was calculated. The projected complex or corridor's percentage impact on horizon-year traffic was determined from this data. In addition, this study recommended that traffic studies should essentially include classified traffic volume counts of the roads in the influence area, occupancy surveys, speed and delay studies of the influence area road network, as well as questionnaire surveys of nearby businesses and complexes. The occupancy survey and traffic volume count will quantify the number of journeys that are currently being made on the influence area network. [13].

Through its case studies, the study emphasised the value of TIA and emphasised the necessity of making TIA a crucial and obligatory criterion for both new construction and capacity augmentation. The influence area and study steps within the case studies in this paper had been adjusted depending on the anticipated impact. It should be noted that both case studies' end assessments call for an analysis of how the proposed development will affect general traffic flow within the influence region over the course of the horizon year term. [2].

Another case study titled “Impacts of road network expansion on landscape ecological risk in a megacity, China: A case study of Beijing” analyzed the spatiotemporal changes of road networks and landscape ecological risk in the research area of Beijing to explore the impacts of road network expansion on ecological risk in the urban landscape. In the data, junctions were represented by nodes and roads by edges and the results showed the following:

a) In the dynamic processes of change in the overall landscape pattern, the changing differences in landscape indices of various landscape types were obvious and were primarily related to land-use type.
b) For the changes in a time series, the expansion of the road kernel area was consistent with the extension of the sub-low-risk area in the urban center, but differences were observed during different stages of development.
c) For the spatial position, the expanding changes in the road kernel area were consistent with the grade changes of the urban central ecological risk, primarily because both had a certain spatial correlation with the expressways.
d) The influence of road network expansion on the ecological risk in the study area had obvious spatial differences [11].

Another study conducted by NTRC for assessing vehicle operating costs for all Classes of Vehicles in 2020 explains the parameters defined for finding VOC and the procedure followed for finding VOC. The examination and evaluation of a nation's transportation system heavily relies on VOC. The output of VOC studies is used for economic feasibility studies for road projects and in the development of annual maintenance plans for the road networks. The procedure followed is as follows:

a) Identify the parameters that need to measure and updated for estimation of VOC in Pakistan,
b) Identify VOC models that better suit the conditions of Pakistan and could be utilized to estimate VOC for all classes of vehicles in Pakistan,
c) To carry out an estimate based on vehicle drivers or operators which could be used to validate the estimate from the VOC models,
d) Determine Financial and Economic VOC for Pakistan.

The major components of the financial cost include fuel consumption, lubricants/engine oil, tires, maintenance and repairs, and depreciation cost. For calculation of VOC a survey was also conducted in which different teams were set to go to bus stations, and toll plazas and asked some basic questions via survey form including monthly income, VMT, maintenance cost, tires cost, fuel cost, engine oil/lubricants cost, etc. A questionnaire survey was conducted from the vehicle operators across Islamabad and Rawalpindi which helped in building a VOC estimate based on the user feedback. The data collection took place in the twin cities of Islamabad and Rawalpindi. Some representative vehicles were selected for whom data collection took place. Following four vehicle classes: a Toyota car, a Toyota Hi-ace, a Hino Bus, and a Hino three-axle Truck were surveyed for VOC.

Apart from this survey, some VOC models were also applied to existing data comprising of different parameters including fuel cost, tires cost, maintenance cost, depreciation cost, engine oil/lubricants cost, etc. for calculation of VOC. The input parameters used in different models were kept identical to have consistency in the estimates for comparison purposes.

The VOC estimates were carried out based on Kenya VOC Model, Nepal VOC Model, and HDM-4 VOC Model. The HDM-4 VOC model is data intensive and based on data collected from different countries of the world and is generalized as well, so is capable to adopt the local conditions of any country [14].

Rawalpindi Ring Road Project is another type of traffic impact study done by Zeeruk Consultants. As the traffic demand in Rawalpindi city has increased due to several reasons which include an increase in population, migration of people from other cities, lack of proper public transport, and an increase in car ownership. This causes a lot of congestion on different routes of Rawalpindi.

e) The main purpose of this study is to estimate future travel demand on the proposed ring road.
f) The proposed project of Rawalpindi Ring Road (R3) will facilitate the bypass traffic and provide an alternative road to the local daily commuters.
g) The R3 project will help to ease the traffic congestion on the internal roads of Islamabad and Rawalpindi.
h) It will also provide access to the airport, motorway, and other land use.

The consultant carried out 24-hour classified traffic counts at different locations within the study area. The total duration of counts was 3-days (72 hours) for each location as per the guidelines by the National Highway Authority (NHA). A total of eleven (11) locations were selected on all major roads. Directional classified Counts were done to estimate existing traffic demand. Video recording units were installed at different locations and traffic counts were extracted from these videos by using the software.

The vehicles were divided into five categories that are Motorcycles, Rickshaws, Passenger Cars, Public Transport, and Heavy vehicles. The public transport consists of HiAce's, Minibus, and large buses. Passenger Car Equivalent was introduced, and traffic counts were recorded in vehicles/day.

Now for travel demand forecasting on these routes growth indicators which include population, registered no of vehicles and traffic growth in the study area needed to be known. These all-growth rates were found in Pakistan Economic Survey 2019, and Punjab Development Statistics 2018. OD Survey was conducted to ascertain road user information. These were done in the same location as the field count survey. 13 TAZs were made to divide the study area. The area and size of the zones were kept small near the proposed alignment whereas for other locations different cities were combined in the same zone. Data obtained from the OD survey was first digitized and converted to 24-hour location-wise traffic count and survey sample size. A 13*13 OD Matrix was then developed for all locations. OD Analysis was done for three categories i.e., passenger cars, public transport, and trucks. Travel time study is used to determine the travel time and average speed of vehicles on the existing corridor with prevailing conditions. Travel Time is one of the measures of effectiveness (MOE) to evaluate the existing road network. Travel time data was collected using a vehicle-mounted GPS receiver. In the last step of Travel Demand Modeling, the trip assignment was done using the equilibrium assignment method. The complete network was coded in VISUM Software to perform the travel demand modelling. The following info was coded for each link in the model:

a) Link ID,
b) Link Name (Road Name),

c) Free Flow Speed,

d) Capacity,

e) Number of Lanes,

f) Average Speed, and

g) Travel Time.

After developing the base model, the Equilibrium Trip Assignment Model was run to load the network. The impendence between zones, travel time and link speeds were adjusted to calibrate the model. In the end, Capacity Analysis was done to evaluate the performance of roads based on the expected traffic demand. Moreover, the capacity analysis also helps to determine the number of lanes required to achieve the target level of service [15].

The goal of the current study was to construct a simulation model that would attempt to simulate sustainable traffic movement along the study corridor in order to analyse the future effects of the traffic caused by the planned hotel in addition to conducting the traffic assessment [6]. In addition to offering several scenarios to better the current conditions, this took into account the potential and preferred circulation in and around the research region.

Data for current traffic impact analysis was calculated using a traffic volume study. Traffic volume study was done for morning and evening peaks for about four hours i.e., from 7:30 am to 11:30 am and 3:30 pm to 7:30 pm. The peak of peak hours was also distinguished. All traffic volume counts were then converted into PCUs. Mode-wise vehicle distribution was also done as the traffic composition was heterogeneous.

The STELLA environment had the model of traffic effect analysis utilizing system dynamics applied. The modeller defines objects representing actual or hypothetical system components using this tool, then establishes functional links between these items. For TIA, various situations were created. The initial scenario considered the current ratio of public and customized automobiles and assumed typical growth from 2009 to 2020.

LOS had also been discovered for the v/c ratio and present traffic. If traffic is permitted to increase at the same rate as it is now, V/c ratio will be at its worst in 2020. A second scenario was created with reasonable public transportation augmentation and restraint on private automobiles in order to attain tolerable LOS. V/c ratio fell under scenario2.

In the third scenario, obtaining LOS 1 was the focus. In order to promote public transportation, the demand-based transportation system was switched to a supply-based one. The sharp drop in the growth of personal vehicles is significantly hindered by the rise in public transportation vehicles.

The current traffic effect research tackled the issue holistically through simulation modelling work to assure permanent solutions, in addition to suggesting short-term management methods. The recommended circulation plan met all parking, mobility, and accessibility requirements along the study stretch, and its execution guaranteed that traffic flowed smoothly.

The amount of travel time is a crucial component of any transportation system. Travelers' choices in the transportation market are significantly influenced by it [16]. The greatest advantage of transportation projects, such as highway and public transportation improvements, is found to be travel time savings, which is also one of the most significant intangibles in the transportation cost-benefit analysis. Travel time value is a major factor in how travellers choose their modes of transportation, and it varies greatly depending on the socioeconomic situation. [17], [5].

After the creation of the time allocation model in the 1960s, the value of travel time (VOT) idea was first established. The time allocation model states that the consumer divides his or her time and money among various activities in order to maximize utility while working within a limited time and financial budget.

VOT varies from country to country, industry to industry, and even from person to person, depending on a number of factors. Savings on travel time are the primary outcome of investments in the growth of transportation infrastructure and services. It may be responsible for as much as 80% of total advantages in industrialised nations. Utilizing standard unit values issued by the appropriate transportation/highway agency, transport investment appraisals estimate the benefits of reduced trip time. Travel time savings are approximated using a recognised national practise in the absence of such unit values. In industrialised nations, the non-working time savings are valued based on the willingness to work, whereas the working time savings are valued based on wage rate (i.e., wage rate + additional costs like taxes, mandatory contributions, etc.).

Travel time is the average amount of time, measured in seconds or minutes per vehicle and including control delay, that it takes for a vehicle to transit a section of a roadway. Even though the difference in time was not saved but rather employed for another activity, the decrease in trip travel time is nevertheless regarded as "saved" time. The quantity of time saved and the value of each unit of time saved are the metrics used by transportation analysts to evaluate the benefits of reduced travel times.

The main portion of the benefits to transportation users is often the savings from shorter trip times. The main advantage of a transportation project is frequently the reduction in travel time. Savings on travel time may also result in lower operational expenses for vehicles. There are some things that have a significant impact on trip time. The influence of the traveler's income, other characteristics, mode of transportation, vehicle type, trip status (on-the-clock and off-the-clock), trip phase (in-vehicle vs. out-of-vehicle), trip purpose (e.g., work price), trip length, size of travel time reduction, and trip mode are among these factors. When traffic volume increases or there is a certain development in the road network so automatically it has an impact on travel time. Travel time can be found by using different methods including HCM Method, COMSIS Method, and BPR Function Method [18].

CHAPTER 3: METHODOLOGY

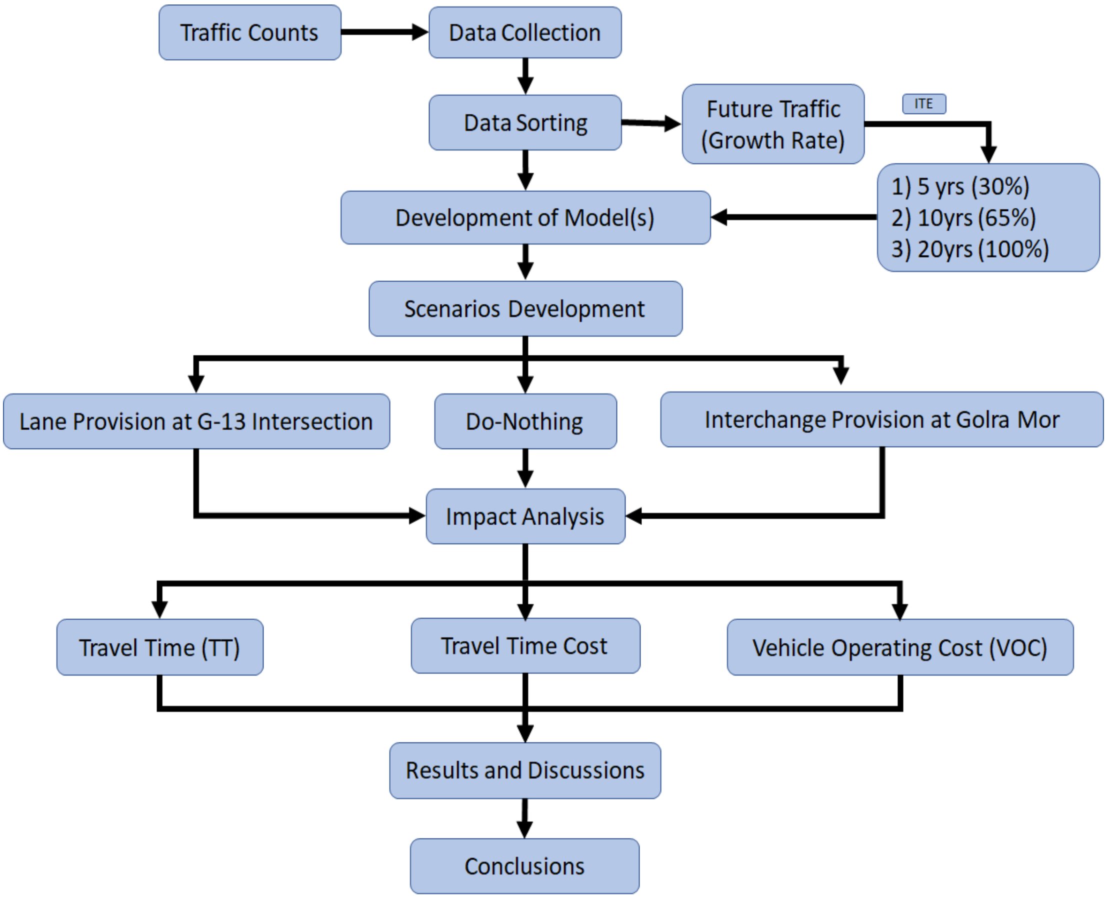

Figure 3-1: Methodology Framework

3.1 Data Collection

Data collection was done manually by traffic counts. Traffic counts were done by mobile video camera for five days a week in the morning and evening peaks. The morning peak was from 9:00 to 10:00 am and evening peak was from 5:00 to 6:00 pm. As pattern is same, so data was collected just for five days of a week. Traffic Counts were done on Monday, Tuesday, Thursday, Friday, and Sunday. Traffic Counts were done at three locations which were GT Road Rawalpindi 26 No Interchange, Golra

Interchange (G-13 Intersection), and Golra Mor. From this peak hour data, a peak 15-minute interval was selected. This peak 15 min interval was converted into hourly traffic volume, and it was considered as the design hourly volume for Traffic Impact Study.

Data collection also includes the data of the housing societies from where traffic volume will be generated in the future. In this specific study area, traffic generation will be from New Developments which are in the form of New Housing Societies as explained earlier. Data for all housing societies have been taken from the RDA website. On the website, housing societies are divided into registered and non-registered societies. Data from both types of societies that come in the study zone will be considered for further analysis. In these housing societies, the area is divided into different blocks. These include residential and commercial blocks. The size of every residential block for each society is given in the Master Plan of each housing scheme. Number of plots of specific sizes are also mentioned. In some housing schemes, commercial areas as just 5% of the total area are mentioned. In some schemes, no. of plots and sizes of commercial plots are also described. All these details can be seen in Table 3-1: Development Units in Housing Societies.

Table 3-1: Development Units in Housing Societies

S/No.	Housing Societies Name	Total no of Plots
1	Top City	6484
2	Airport Green Garden	5124
3	Gandhara City	345
4	Elite Reverie	1297
5	Taj Residencia (Extension)	1499
6	Faisal Town	6039
7	PECHS	2118

8	Taj Residencia	260
9	Marble Arch	1719
10	Faisal Hills	12850
11	Khudadad City	962
12	Faisal Margalla City	3962
13	B-17	18098

3.2 Data Sorting

The traffic volume data collected by traffic count survey is heterogeneous and it consists of different types of vehicles. These vehicles include cars, 4WD, trucks, buses, motorcycles, rickshaws, and tractor trolley. For TIA this diverse traffic volume needs to be converted into PCU [19], [20]. For this conversion, PCU values were taken from a report published by RDA regarding Rawalpindi Ring Road Project. These PCU values were then used to convert all vehicles in the form of PCU. PCU table is placed at Table 3-2: PCU/PCE Values.

Table 3-2: PCU/PCE Values

S/No.	Vehicle Classification	PCE Factor Value
1	Motorcycles	0.25
2	Rickshaw	0.5
3	Car/Jeeps/vans/Taxi	1.00
4	Minibus/Coaster/HiAce	1.5
5	Large Buses	2.5
6	2- Axle Truck	1.5
7	3- Axle Truck	2.5
8	4- Axle Truck	3.5
9	> 5-Axle Truck	4.0

3.3 Traffic Imposed through New Developments

Currently, the societies are in development stages. In urban area, the masterplan needs to be revised after the 20 years due to urbanization. Therefore, we have assumed the developments impacts on the existing road network in three (3) stages. In first stage, we have considered 30 percent in five years. In second stage, it will consider 65 percent in 10 years' time. Finally, the 100 percent development will be in 20 years' time. For upcoming years, the traffic volume growth from housing societies will be found by using ITE Manual Trip Generation Rates in Table 3-3: ITE Trip Generation Rates [21].

The traffic growth from future developments will be distributed on the above described three intersections. Table 3-3: ITE Trip Generation Rates explains different land uses and their respective equations along with the units. The concerned area for future traffic in research is single-family and apartments having codes 210 and 220 respectively. The equations shown in the table can be used to calculate future traffic. In this table, X is number of occupied dwelling units and in some cases, X is GFA occupied by the specific residential plot, and 1K GFA=1000 square feet of GFA. These can be seen in Table 3-3: ITE Trip Generation Rates below.

Table 3-3: ITE Trip Generation Rates

S/No.	Land Use	Code	Units (X)	Equation
1	Light Industrial	110	1K GFA	Trips = 0.98*(X)
2	Industrial Park	130	1K GFA	Ln(T)=0.854*Ln(X)+0.712
3	Manufacturing	140	1K GFA	T = 0.776*(X) – 12.885
4	Single Family	210	Occ. DU	Ln(T)=0.901*Ln(X)+0.527
5	Apartment	220	Occ. DU	T = 0.541*(X) + 18.743
6	Res. Condo	230	Occ. DU	Ln(T)=0.827*Ln(X)+0.309
7	Mobile Home	240	Occ. DU	Ln(T)=0.897*Ln(X)–0.044
8	Retirement Com	250	Occ. DU	DU T = 0.269*(X) – 2.514

9	Residential PUD	270	Occ. DU	Ln(T)=0.896*Ln(X)+0.265
10	County Park	412	Acres	T = 0.06*(X)
11	General Office	710	GFA	T = 1.121*(X) + 79.295
12	Medical Office	720	1K GFA	Ln(T)=0.921*Ln(X)+1.476
13	Office Park	750	1K GFA	T = 1.213*(X)+106.215
14	Research Centre	760	1K GFA	Ln(T)=0.832*Ln(X)+1.060
15	Business Park	770	1K GFA	Ln(T)=0.915*Ln(X)+0.782
16	Shopping Centre	820	1K GFA	Ln(T)=0.660*Ln(X)+3.403

We have used serial number 4 and 5 required equation and other requisite information for this research study.

3.4 Models Development in Synchro

After data sorting, the data has been classified as current traffic data and future traffic data. Current Traffic Data and Future Traffic Data are the same as explained above. For analyzing the data sorted Highway Capacity Manual and software needs to be used. The software used for the analysis of parameters is Synchro. Synchro is software used to design, model, optimize, simulate, and animate signalized and non-signalized intersections (including roundabouts). The same software is used here in research work for analyzing the parameters.

Models are developed in Synchro for current, 30% imposed traffic data, 65% imposed traffic data, 100% imposed traffic data and for scenarios which are developed as mitigation strategies.

3.5 Scenarios Development for Mitigation Strategies

For further study, three different scenarios are developed. These scenarios are Do-nothing (existing situation), Do-Minimum (lane addition), and Do-Something (provision of freeway ramps).

3.5.1 Do-Nothing

In a do-nothing scenario, analysis is done on base year's data/current data, data with 30% development, data with 65% development, and data with 100% development. In this scenario, it is assumed that there is no extension of the roadway neither any interchange provision for the road network.

3.5.2 Do-Minimum

This scenario is developed on an assumption that due to developments and population increase there will be a huge traffic influx from these housing societies. With these developments, the amount of traffic will increase to a larger level so it is assumed that the current road network will not be enough to hold the traffic volume. So, to accommodate the future traffic there may be a solution to this. For this, the number of lanes on the current road network may be increased.

So, in the do-minimum scenario, an additional lane is assumed for Srinagar Highway (Ex-Kashmir Highway) at Golra Interchange (G-13 Intersection) as shown in the Figure 3-2: Model designed in Synchro .

Figure 3-2: Model designed in Synchro

3.5.3 Do-Something

We have built a scenario on basis of current proposed scheme being announced at Golra Morr to introduce an interchange by replacing intersection. Thus, we have studied the impact of interchange provision at proposed intersection. An underpass as suggested by NHA for Golra Mor is assumed in this study and its effect on parameters is studied while doing analysis by Synchro and other equations.

3.6 Impact Analysis

Impact Analysis is a specialized engineering study that determines the potential traffic impacts of a proposed traffic generator. Moreover, the impact of developments along the corridor in monetary terms for the parameters will be found in the following sections. In this case, as described above, three different scenarios which are explained above will be analyzed by model development.

The main parameters to be discussed in detail upon which impact analysis relies are:

3.6.1 Travel time (TT)

The average time spent by vehicles traversing a highway segment, including control delay, in seconds per vehicle or minutes per vehicle is called travel time.

Travel time can be found by using HCM Method [22]. According to HCM Method, the travel time can be calculated by the Equation:

$$TT_{15} = \frac{VkmT_{15}}{ATS} \qquad \text{(Eq. 3-1)}$$

Where,

TT_{15} = Total travelled time for all vehicles on the analyzed segment during the peak 15-min period (Veh-h),

$VkmT_{15}$ = total travel on the analysis segment during the peak 15-min period (Veh-km), and

ATS = Average travel speed for both directions of travel combined (km/h)

As our analysis was for a whole peak hour, so TT_{15} and $VkmT_{15}$ were converted into an hour by multiplying them with four. For the above equation, total travel on the analysis segment and average travel speed was known. Total travel was calculated from point A where the vehicles start to move along the segment in a link to end point B of the intersection. ATS for each segment of the intersection was assumed and these were different for through and turning traffic.

The same parameter was analyzed by Synchro software as well. Synchro is very helpful software for the calculation of exact travel time by generating a report. The input parameters required for analysis in Synchro were a map of the intersection and traffic volume data. Map for each intersection for Synchro was taken by a scaled image from Google Earth in jpeg format. Then on the scaled image of the intersection, links and nodes were drawn. As traffic volume was known by traffic count survey, both these parameters were incorporated in Synchro.

After the incorporation of the required data, the model was run for checking any errors. The model was free of error and then a report was generated for each synchro model. From this report, travel time and travel distance were easily known which was helpful for further calculation.

3.6.2 *Travel Time Cost*

Value of travel time plays a key role in traveler's mode choice behavior and varies significantly with varying socioeconomic conditions. Travel time saving is often the main benefit of a transportation project.

For travel time savings equation from HCM is used [18].

$$Travel\ Time\ Savings\ = (Occupancy\ of\ Vehicle) X\ (AADT\ X\ Travel\ Time\ Saved) X\ (Unit\ Travel\ Time\ Cost) \qquad \text{(Eq. 3-2)}$$

This equation was used in paper for calculation of travel time savings of Rawalpindi Bypass Pakistan with varying alternatives. In our case, instead of AADT in the equation, ADT was used. Travel time savings can also be calculated from the NTRC published the latest report in May 2020. In this report, different models have been used for the calculation of different parameters including the value of travel time or the value of travel cost. For this analysis, Highway Development & Management (HDM-4) model has been used as it is prepared for developing countries and is used worldwide [14]. This model calculates the value of travel time in terms of Rs/1000 vehicle-km. The unit Rs/1000 vehicle-km means, the cost in rupees per 1000 km mileage of the vehicle.

The mileage of traffic volume traversing the three intersections to be analyzed was known by Synchro software. Moreover, the value of time cost for different types of vehicles was given but as the whole traffic volume was converted into PCU by using Table 3-2: PCU/PCE Values.

The value of travel time for cars was selected for further analysis. As explained earlier, the value of travel time was for 1000 km mileage, so, it was adjusted for the mileage at intersections. Now, the cost of a unit vehicle at the analyzed intersection was known. It was then multiplied with the traffic volume of each segment of the intersection to get the total value of travel time. This method was used to calculate the value of travel time for every scenario assumed and every model developed. Further calculation of all readings was done in an excel sheet.

3.6.3 Vehicle Operating Cost (VOC)

VOC means the operational cost of vehicles traversing a roadway segment for a specific length.

Vehicle operating costs can be easily calculated by using the equations of the Hepburn Model already used by a study of Rawalpindi Bypass Road. [14], [18] These equations differ with respect to speed. These equations are as follows:

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

$$VOC = C + \frac{D}{S} \quad \text{(Eq. 3-3)}$$

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

$$VOC = a_o + a_1 S + aS^2 \quad \text{(Eq. 3-4)}$$

Where:

VOC (cents/mile),

S = speed (mph)

and C, D, a_o, a_1, and a_2 are coefficients that are functions of vehicle class.

The coefficients for the Hepburn model were considered from Table 3-4: Coefficients of Hepburn Model [18].

Table 3-4: Coefficients of Hepburn Model

S/No.	**Vehicle Type**	**C**	**D**	**a_o**	**a_1**	**a_2**
1	Small automobile	24.8	45.5	27.2	-0.035	0.00021
2	Medium automobile	28.5	95.3	33.5	-0.058	0.00029
3	Large automobile	29.8	163.4	38.1	-0.093	0.00033

Moreover, the same can be done from NTRC's uploaded VOCs in 2020. In this HDM-4 Model, values are used for the calculation of VOC. Values of VOC in HDM-4 Model are given in Rs/1000 vehicle-km, these values are converted into Rs/vehicle-km.

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CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Current Scenarios

In current scenarios, no future traffic amount is imposed on road network. All the analysis is done on existing/current road network with existing/current traffic data of base year. The results of parameters for analysis are at 4.1.2. in the tabular form. The data in the table below is peak of peaks i.e., as the analysis was of am and pm peaks, so from this am and pm peak hour, the hour which had more traffic volume was selected for analysis and same has been mentioned in tables. Same peak hour data is used to draw the graphs for data. In this table travel time is shown in seconds travel time cost in rupees and VOC of both models i.e., NTRC and Hepburn Model is in rupees.

4.1.1 Traffic Counts

The data is collected on Monday, Tuesday, Thursday, Friday, and Sunday respectively. We have presented here tables of traffic counts with only the peak day. Rest of the tables regarding all other days are compiled and enclosed in the annexure. These values of the traffic counts are used for the further analysis.

Table 4-1: Monday Peak Hour Current Traffic Volume

Intersection	Peak Hour	East Bound				West Bound				North Bound				South Bound			
		R	T	L1	L2	R	T	L1	L2	R	T	L1	L2	R	T	L1	L2
G-13 Interchange	am	-	4479	928	157	-	3729	842	202	-	1091	264	150	-	629	395	112
	pm	-	4078	549	97	-	3976	925	168	-	951	267	161	-	569	353	101
Golra Mor	am	-	3221	1358	0	-	3366	737	0	-	0	452	0	-	0	1218	0
	pm	-	3024	1215	0	-	3053	559	0	-	0	353	0	-	0	1110	0
26 No Interchange	am	-	2332	1265	156	-	2383	1629	188	-	2354	998	0	-	2162	744	0
	pm	-	2313	1292	160	-	2247	1537	177	-	2240	998	0	-	2153	703	0

Table 4-2: Monday Peak Hour 30% Imposed Traffic Volume

Intersection	Peak Hour	East Bound				West Bound				North Bound				South Bound			
		R	T	L1	L2	R	T	L1	L2	R	T	L1	L2	R	T	L1	L2
G-13 Interchange	am	-	6773	1398	204	-	5635	1260	262	-	1651	441	195	-	935	591	146
	pm	-	6222	856	126	-	6048	1411	218	-	1426	401	209	-	871	538	131
Golra Mor	am	-	4862	2061	0	-	5114	1121	0	-	0	665	0	-	0	1858	0
	pm	-	4576	1825	0	-	4593	891	0	-	0	513	0	-	0	1696	0
26 No Interchange	am	-	3522	1906	203	-	3588	2466	244	-	3537	1505	0	-	3526	1129	0
	pm	-	3530	1977	208	-	3410	2345	230	-	3406	1522	0	-	3262	1073	0

Table 4-3: Monday Peak Hour 65% Imposed Traffic Volume

Intersection	Peak Hour	East Bound				West Bound				North Bound				South Bound			
		R	T	L1	L2	R	T	L1	L2	R	T	L1	L2	R	T	L1	L2
G-13 Interchange	am	-	7317	1509	259	-	6087	1360	333	-	1783	426	247	-	1008	637	185
	pm	-	6222	856	160	-	6048	1411	277	-	1426	401	265	-	871	538	166
Golra Mor	am	-	5252	2228	0	-	5529	1212	0	-	0	716	0	-	0	2009	0
	pm	-	4944	1969	0	-	4959	895	0	-	0	551	0	-	0	1835	0
26 No Interchange	am	-	3805	2058	257	-	3874	2665	310	-	3818	1625	0	-	3516	1220	0
	pm	-	3819	2139	264	-	3686	2537	292	-	3683	1646	0	-	3525	1160	0

Table 4-4: Monday Peak Hour 100% Imposed Traffic Volume

Intersection	Peak Hour	East Bound				West Bound				North Bound				South Bound			
		R	T	L1	L2	R	T	L1	L2	R	T	L1	L2	R	T	L1	L2
G-13 Interchange	am	-	10280	2116	314	-	8548	1900	404	-	2506	596	300	-	1404	891	224
	pm	-	9500	1288	194	-	9216	2154	336	-	2152	606	222	-	1333	821	202
Golra Mor	am	-	7372	3137	0	-	7787	1707	0	-	0	991	0	-	0	2835	0
	pm	-	7089	2812	0	-	7087	1271	0	-	0	772	0	-	0	2645	0
26 No Interchange	am	-	5342	2886	312	-	5430	3747	376	-	5346	2280	0	-	4930	1716	0
	pm	-	5390	3023	220	-	5189	3581	354	-	5189	2323	0	-	4358	1638	0

4.1.2 Tables of Current Traffic

Table 4-5: Monday Peak Hour Current Traffic Data Analysis

S/No.	Intersection	Travel Time (seconds)	Travel Time Cost (Rupees)	VOC w.r.t NTRC Model (Rupees)	VOC w.r.t Hepburn Model (Rupees)
1	Golra Interchange	385.3	40281	747858	1688588
2	Golra Mor	135.6	18325	193546	254352
3	Rawalpindi GT Road 26 No Interchange	372.8	54487	1015151	2279736
4	Do-Minimum Scenario at G-13 Chowk	325.4	30345	654321	1598567
5	Do-Something Scenario at Golra Mor	100.4	10023	154326	219864

Table 4-6: Tuesday Peak Hour Current Traffic Data Analysis

S/No.	Intersection	Travel Time (seconds)	Travel Time Cost (Rupees)	VOC w.r.t NTRC Model (Rupees)	VOC w.r.t Hepburn Model (Rupees)
1	Golra Interchange	385.3	33481	782856	1474975
2	Golra Mor	135.6	15953	196754	249981
3	Rawalpindi GT Road 26 No Interchange	372.8	42493	991400	1859109
4	Do-Minimum Scenario at G-13 Chowk	325.4	25678	557678	123456
5	Do-Something Scenario at Golra Mor	100.4	9879	154390	219856

Table 4-7: Thursday Peak Hour Current Traffic Data Analysis

S/No.	**Intersection**	**Travel Time (seconds)**	**Travel Time Cost (Rupees)**	**VOC w.r.t NTRC Model (Rupees)**	**VOC w.r.t Hepburn Model (Rupees)**
1	Golra Interchange	385.3	32943	767908	1446717
2	Golra Mor	135.6	15110	196745	259845
3	Rawalpindi GT Road 26 No Interchange	372.8	42615	1009857	1889462
4	Do-Minimum Scenario at G-13 Chowk	325.4	25678	567313	1254362
5	Do-Something Scenario at Golra Mor	100.4	8500	164329	217809

Table 4-8: Friday Peak Hour Current Traffic Data Analysis

S/No.	**Intersection**	**Travel Time (seconds)**	**Travel Time Cost (Rupees)**	**VOC w.r.t NTRC Model (Rupees)**	**VOC w.r.t Hepburn Model (Rupees)**
1	Golra Interchange	385.3	35415	810534	1530845
2	Golra Mor	135.6	15718	209865	267890
3	Rawalpindi GT Road 26 No Interchange	372.8	43170	1018180	1906330
4	Do-Minimum Scenario at G-13 Chowk	325.4	27654	606754	1256839
5	Do-Something Scenario at Golra Mor	100.4	11679.0	167699	217854

Table 4-9: Sunday Peak Hour Current Traffic Data Analysis

S/No.	Intersection	Travel Time (seconds)	Travel Time Cost (Rupees)	VOC w.r.t NTRC Model (Rupees)	VOC w.r.t Hepburn Model (Rupees)
1	Golra Interchange	385.3	33982	779141	1471366
2	Golra Mor	135.6	13784	191459	250989
3	Rawalpindi GT Road 26 No Interchange	372.8	43622	1025394	1920770
4	Do-Minimum Scenario at G-13 Chowk	325.4	25987	587920	1230921
5	Do-Something Scenario at Golra Mor	100.4	10564	153421	207653

4.1.3 Graphs of Current Traffic

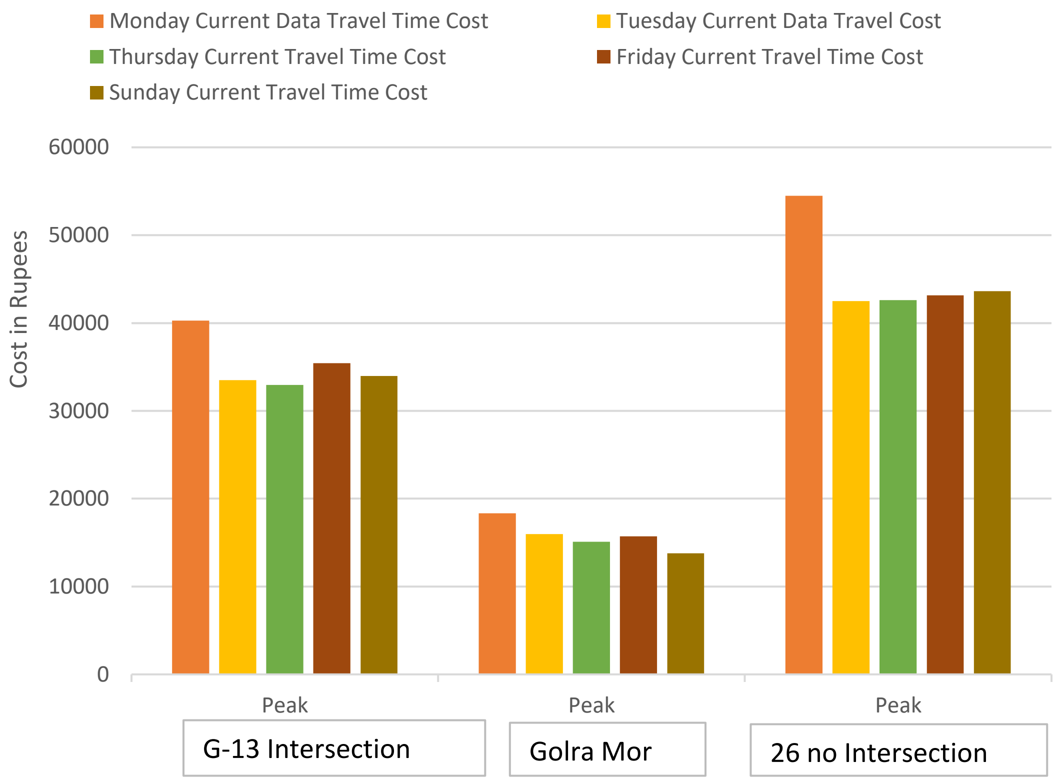

Figure 4-1: Current Data Travel Time Cost

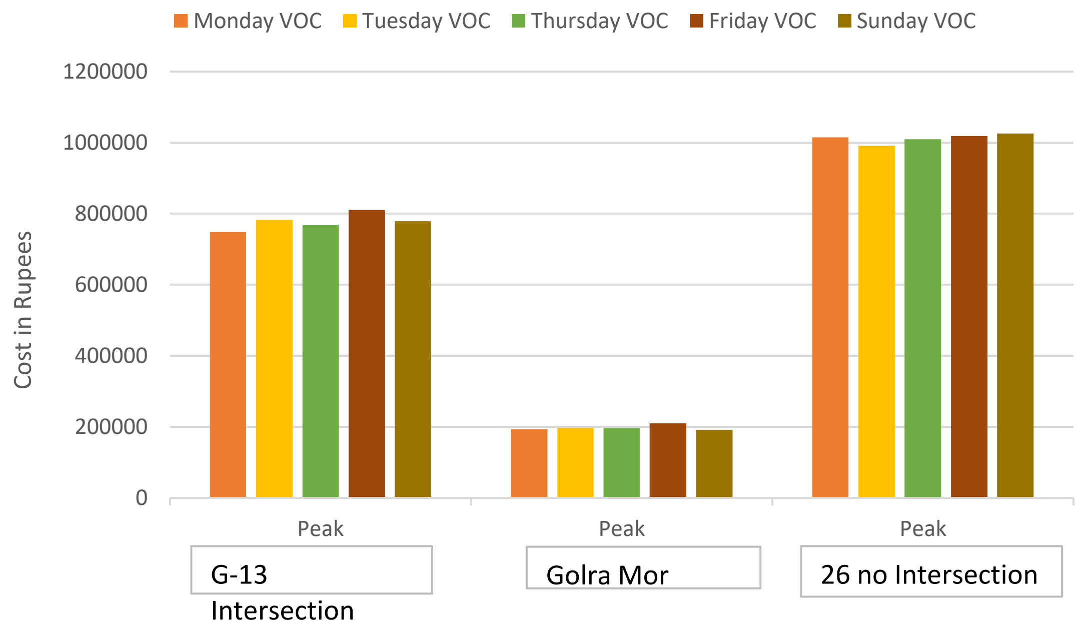

Figure 4-2: Current Data VOC according to NTRC Model

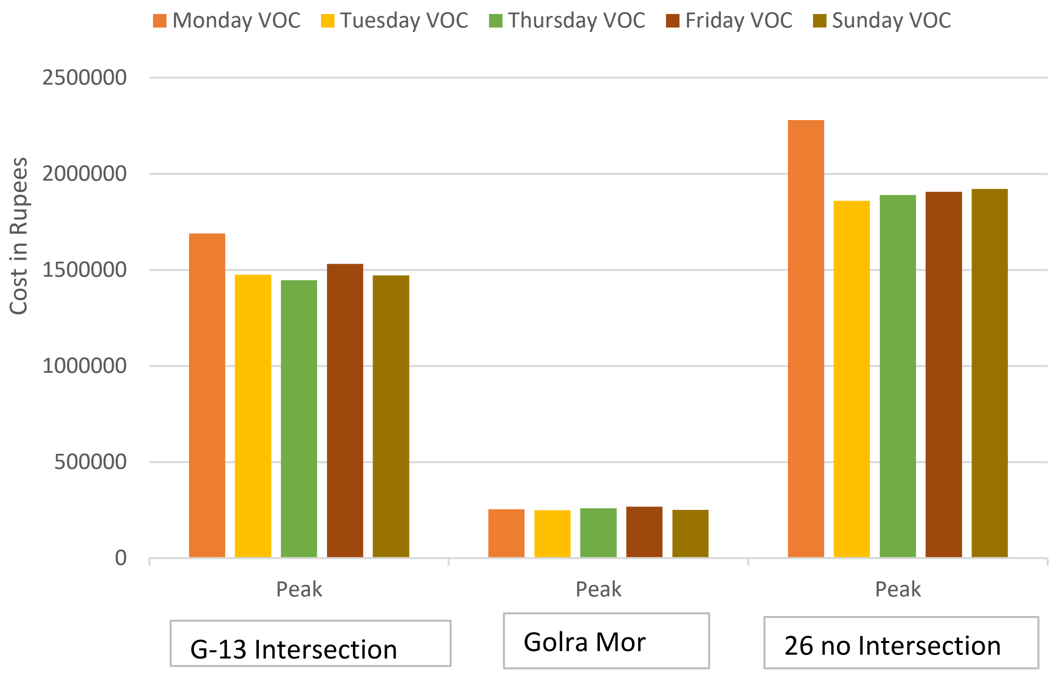

Figure 4-3: Current Data VOC according to Hepburn Model

4.2 Do-nothing scenario

In this scenario, data is further of three types and no mitigation strategies are applied on this data. As in methodology, it is explained that future data will be imposed on current data for further analysis. Same is done here in all sections in which respective future traffic volume is imposed on current road traffic volume. These all sections are explained briefly at 4.2.1, 4.2.2 and 4.2.3

4.2.1 30% Development in five years

The first section of this scenario is 30% imposed data on existing road networks in which traffic of future five years is imposed on current traffic. This new traffic volume comes from development of housing societies in the study area. The new traffic volume being generated from these societies is imposed on existing road network with current traffic volume. As a result, the values of parameters get changed.

4.2.1.1 Tables with 30 percent Imposed Traffic

Table 4-10: Monday Peak Hour Traffic Data Analysis for 5 years

S/No.	Intersection	Travel Time (seconds)	Travel Time Cost (Rupees)	VOC w.r.t NTRC Model (Rupees)	VOC w.r.t Hepburn Model (Rupees)
1	Golra Interchange	420.3	60573	1669356	2734870
2	Golra Mor	150.2	27818	309875	464321
3	Rawalpindi GT Road 26 No Interchange	386.2	83188	2299088	3713762
4	Do-Minimum Scenario at G-13 Chowk	339.6	50467	1456780	2556789
5	Do-Something Scenario at Golra Mor	105.6	12234	239874	413267

Table 4-11: Tuesday Peak Hour Traffic Data Analysis for 5 years

S/No.	Intersection	Travel Time (seconds)	Travel Time Cost (Rupees)	VOC w.r.t NTRC Model (Rupees)	VOC w.r.t Hepburn Model (Rupees)
1	Golra Interchange	420.3	52634	1222782	2306010
2	Golra Mor	150.2	25302	312567	436809
3	Rawalpindi GT Road 26 No Interchange	386.2	67342	1566758	2939231
4	Do-Minimum Scenario at G-13 Chowk	339.6	39876	1023456	2006729
5	Do-Something Scenario at Golra Mor	105.6	11089	256789	403218

Table 4-12: Thursday Peak Hour Traffic Data Analysis for 5 years

S/No.	Intersection	Travel Time (seconds)	Travel Time Cost (Rupees)	VOC w.r.t NTRC Model (Rupees)	VOC w.r.t Hepburn Model (Rupees)
1	Golra Interchange	420.3	52104	1205356	2273415
2	Golra Mor	150.2	24066	318945	464312
3	Rawalpindi GT Road 26 No Interchange	386.2	67918	1604431	3003276
4	Do-Minimum Scenario at G-13 Chowk	339.6	40859	997563	2012857
5	Do-Something Scenario at Golra Mor	105.6	11677	236790	398764

Table 4-13: Friday Peak Hour 30% Traffic Data Analysis for 5 years

S/No.	Intersection	Travel Time (seconds)	Travel Time Cost (Rupees)	VOC w.r.t NTRC Model (Rupees)	VOC w.r.t Hepburn Model (Rupees)
1	Golra Interchange	420.3	55323	1258492	2379035
2	Golra Mor	150.2	24665	314567	463421
3	Rawalpindi GT Road 26 No Interchange	386.2	67716	1594957	2986806
4	Do-Minimum Scenario at G-13 Chowk	339.6	42378	1018781	2010785
5	Do-Something Scenario at Golra Mor	105.6	13561.0	239854	412390

Table 4-14-Sunday: Peak Hour 30% Traffic Data Analysis for 5 years

S/No.	Intersection	Travel Time (seconds)	Travel Time Cost (Rupees)	VOC w.r.t NTRC Model (Rupees)	VOC w.r.t Hepburn Model (Rupees)
1	Golra Interchange	420.3	53704	1222082	2310468
2	Golra Mor	150.2	22131	307122	453213
3	Rawalpindi GT Road 26 No Interchange	386.2	69793	1635071	3064307
4	Do-Minimum Scenario at G-13 Chowk	339.6	42890	1023456	999345
5	Do-Something Scenario at Golra Mor	105.6	11245	243679	403218

4.2.1.2 Graphs with 30 percent Imposed Traffic

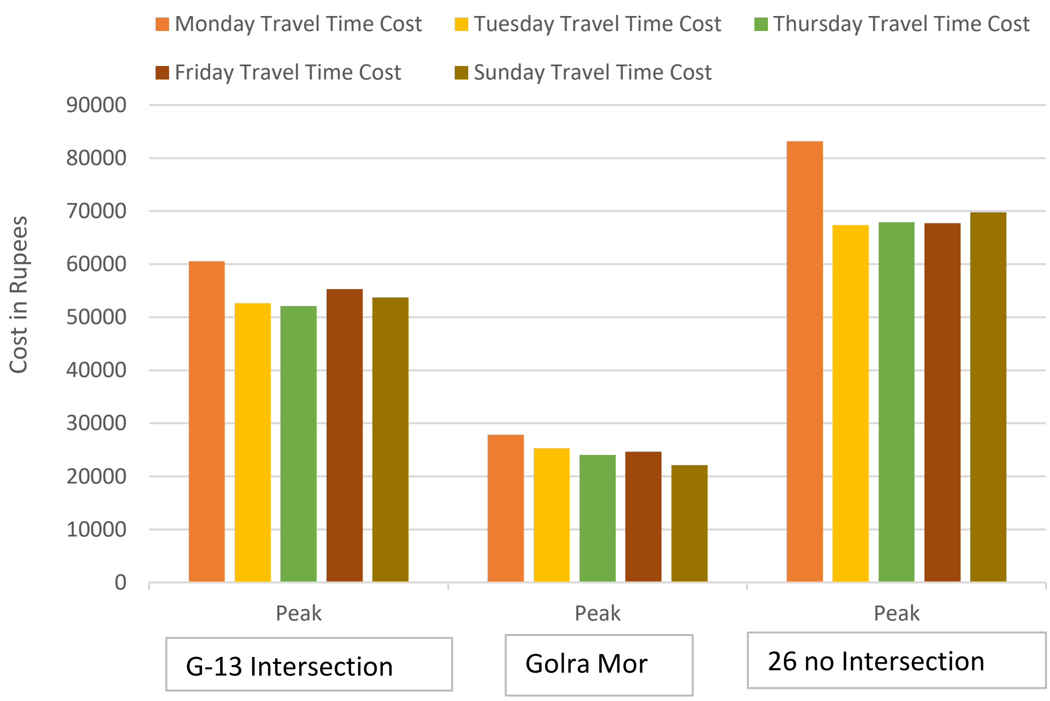

Figure 4-4: 30% Imposed Data Travel Time Cost

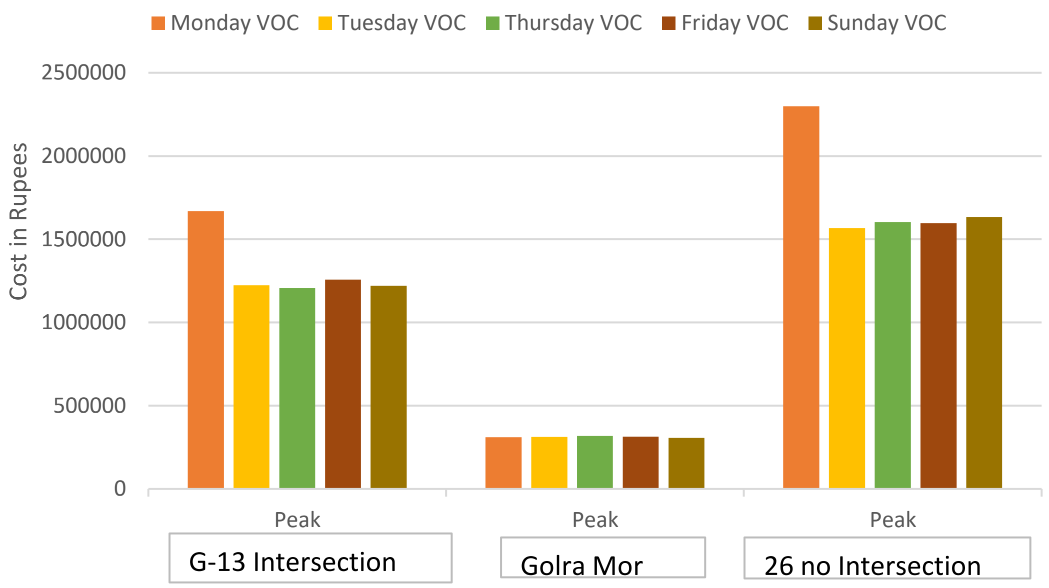

Figure 4-5: 30% Imposed VOC according to NTRC Model

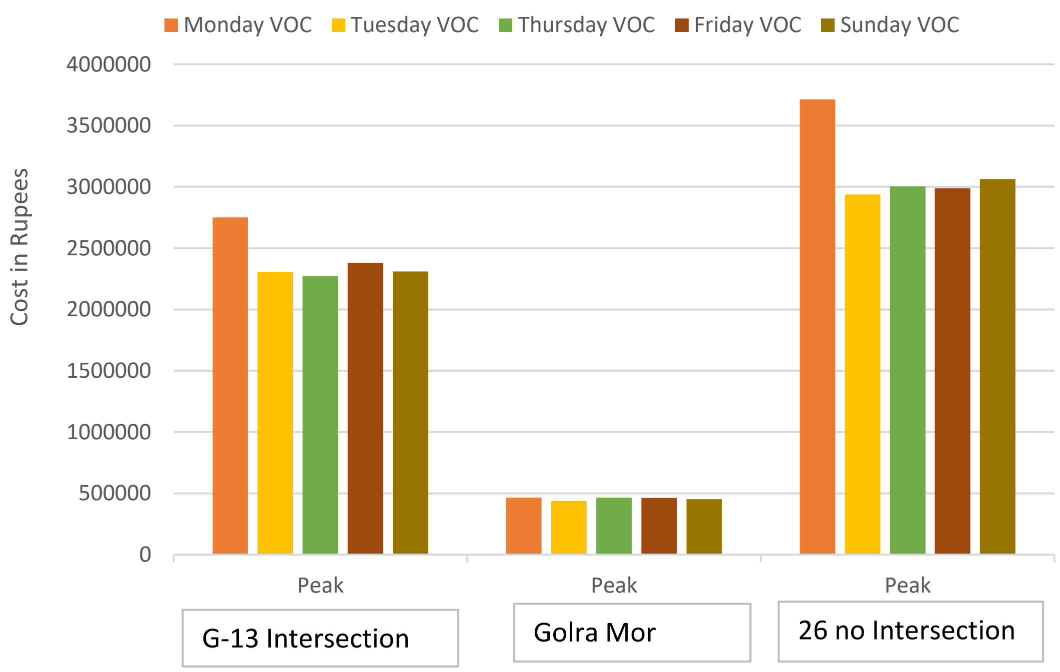

Figure 4-6: 30% Imposed Data VOC according to Hepburn Model

4.2.2 65% Development in Ten Years

The second section of do-nothing scenario is 65% development in ten years. In these ten years, due to development of different housing societies more traffic volume is generated. This traffic volume is imposed on current traffic. As a result, there is there is significant change in values of all parameters. This change is an increase in travel time, travel time cost and VOC. This data is shown in tabular form and represented in graphical form as well. Travel time is mentioned in seconds, travel cost and VOC in rupees.

4.2.2.1 Tables with 65% Imposed Traffic

Table 4-15: Monday Peak Hour Traffic Data Analysis

S/No.	Intersection	Travel Time (seconds)	Travel Time Cost (Rupees)	VOC w.r.t NTRC Model (Rupees)	VOC w.r.t Hepburn Model (Rupees)
1	Golra Interchange	445.6	65674	2034567	2751165
2	Golra Mor	160.3	29832	334521	554368
3	Rawalpindi GT Road 26 No Interchange	390.0	88703	2464304	3693434
4	Do-Minimum Scenario at G-13 Chowk	368.6	58769	1765837	2587690
5	Do-Something Scenario at Golra Mor	115.4	15438	276543	49856

Table 4-16: Tuesday Peak Hour Traffic Data Analysis

S/No.	Intersection	Travel Time (seconds)	Travel Time Cost (Rupees)	VOC w.r.t NTRC Model (Rupees)	VOC w.r.t Hepburn Model (Rupees)
1	Golra Interchange	445.6	57592	1344691	2533906
2	Golra Mor	160.3	27644	329876	564320
3	Rawalpindi GT Road 26 No Interchange	390.0	73429	1711347	3209668
4	Do-Minimum Scenario at G-13 Chowk	368.6	45639	1107838	2245786
5	Do-Something Scenario at Golra Mor	115.4	15432	265489	489756

Table 4-17: Thursday Peak Hour Traffic Data Analysis

S/No.	Intersection	Travel Time (seconds)	Travel Time Cost (Rupees)	VOC w.r.t NTRC Model (Rupees)	VOC w.r.t Hepburn Model (Rupees)
1	Golra Interchange	445.6	57011	1324351	2496229
2	Golra Mor	160.3	26176	321456	554312
3	Rawalpindi GT Road 26 No Interchange	390.0	74139	1754648	3283582
4	Do-Minimum Scenario at G-13 Chowk	368.6	45321	1238931	21757890
5	Do-Something Scenario at Golra Mor	115.4	14356	267845	490012

Table 4-18: Friday Peak Hour Imposed Traffic Data Analysis

S/No.	**Intersection**	**Travel Time (seconds)**	**Travel Time Cost (Rupees)**	**VOC w.r.t NTRC Model (Rupees)**	**VOC w.r.t Hepburn Model (Rupees)**
1	Golra Interchange	445.6	60458	1382108	2610681
2	Golra Mor	160.3	26935	332456	554321
3	Rawalpindi GT Road 26 No Interchange	390.0	73704	1738763	3255355
4	Do-Minimum Scenario at G-13 Chowk	368.6	53467	1300987	2208791
5	Do-Something Scenario at Golra Mor	115.4	15321.0	275643	496734

Table 4-19: Sunday Peak Hour Imposed Traffic Data Analysis

S/No.	**Intersection**	**Travel Time (seconds)**	**Travel Time Cost (Rupees)**	**VOC w.r.t NTRC Model (Rupees)**	**VOC w.r.t Hepburn Model (Rupees)**
1	Golra Interchange	445.6	58809	1345130	2541043
2	Golra Mor	160.3	24089	334613	554329
3	Rawalpindi GT Road 26 No Interchange	390.0	76,215	1788704	3351365
4	Do-Minimum Scenario at G-13 Chowk	368.6	46893	1145671	2223759
5	Do-Something Scenario at Golra Mor	115.4	15643	276543	498734

4.2.2.2 Graphs with 65 percent Imposed Traffic

Figure 4-7: 65% Imposed Data Travel Time Cost

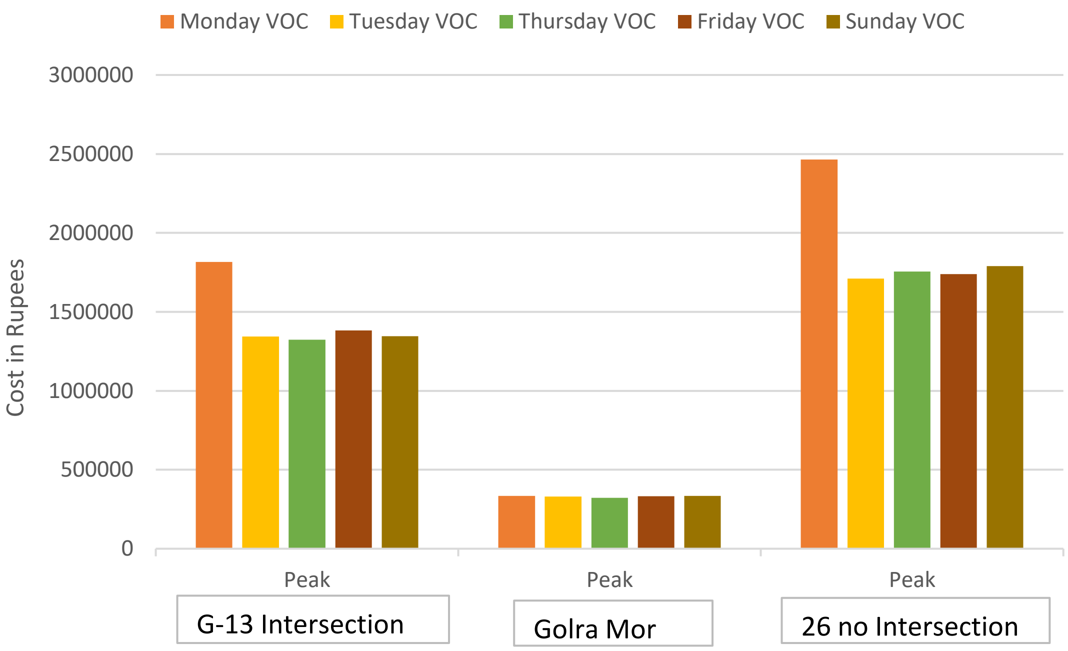

Figure 4-8: 65% Imposed Data VOC according to NTRC Model

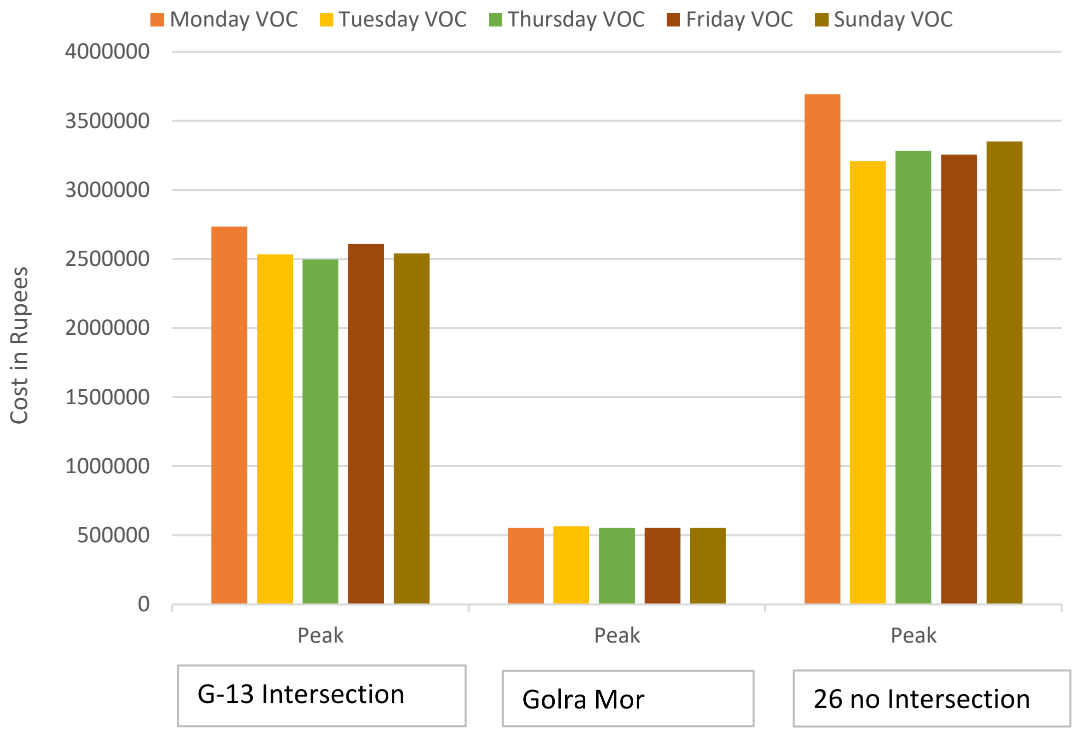

Figure 4-9: 65% Imposed Data VOC according to Hepburn Model

4.2.3 100% Development in twenty years

The third section of do-nothing scenario is 100% development in twenty years. As after twenty years master plan changes. So, it is assumed that societies are 100% developed after twenty years. So, after these twenty years, due to development of different housing societies more traffic volume is generated. This traffic volume is imposed on current traffic. As a result, there is there is significant change in values of all parameters. There is an increase in travel time, travel time cost and VOC. This data is shown in tabular form and represented in graphical form as well. Travel time is mentioned in seconds, travel cost and VOC in rupees.

4.2.3.1 Tables with 100% Imposed Traffic

Table 4-20: Monday Peak Hour Imposed Traffic Data Analysis

S/No.	Intersection	Travel Time (seconds)	Travel Time Cost (Rupees)	VOC w.r.t NTRC Model (Rupees)	VOC w.r.t Hepburn Model (Rupees)
1	Golra Interchange	479.4	91681	2522294	3825305
2	Golra Mor	172.4	42147	478956	634510
3	Rawalpindi GT Road 26 No Interchange	400.3	124145	3444295	5191639
4	Do-Minimum Scenario at G-13 Chowk	390.2	81456	2056789	3456779
5	Do-Something Scenario at Golra Mor	120.6	18564	431289	584512

Table 4-21: Tuesday Peak Hour Imposed Traffic Data Analysis

S/No.	Intersection	Travel Time (seconds)	Travel Time Cost (Rupees)	VOC w.r.t NTRC Model (Rupees)	VOC w.r.t Hepburn Model (Rupees)
1	Golra Interchange	479.4	82274	1910677	3603347
2	Golra Mor	172.4	39649	484004	623450
3	Rawalpindi GT Road 26 No Interchange	400.3	105501	2453543	4603116
4	Do-Minimum Scenario at G-13 Chowk	390.2	71540	1654932	3156789
5	Do-Something Scenario at Golra Mor	120.6	17654	421674	574321

Table 4-22: Thursday Peak Hour Imposed Traffic Data Analysis

S/No.	Intersection	Travel Time (seconds)	Travel Time Cost (Rupees)	VOC w.r.t NTRC Model (Rupees)	VOC w.r.t Hepburn Model (Rupees)
1	Golra Interchange	479.4	81713	1887534	3560771
2	Golra Mor	172.4	37701	487652	634890
3	Rawalpindi GT Road 26 No Interchange	400.3	106777	2520718	4718891
4	Do-Minimum Scenario at G-13 Chowk	390.2	68543	1506543	3167895
5	Do-Something Scenario at Golra Mor	120.6	17546	421378	564321

Table 4-23: Friday Peak Hour Imposed Traffic Data Analysis

S/No.	Intersection	Travel Time (seconds)	Travel Time Cost (Rupees)	VOC w.r.t NTRC Model (Rupees)	VOC w.r.t Hepburn Model (Rupees)
1	Golra Interchange	479.4	86125	1958682	3702689
2	Golra Mor	172.4	38364	485457	625698
3	Rawalpindi GT Road 26 No Interchange	400.3	105388	2482880	4649416
4	Do-Minimum Scenario at G-13 Chowk	390.2	74987	1706542	3409878
5	Do-Something Scenario at Golra Mor	120.6	18100.0	413267	573451

Table 4-24: Sunday Peak Hour Imposed Traffic Data Analysis

S/No.	Intersection	Travel Time (seconds)	Travel Time Cost (Rupees)	VOC w.r.t NTRC Model (Rupees)	VOC w.r.t Hepburn Model (Rupees)
1	Golra Interchange	479.4	84,234	1,915,156	3,621,190
2	Golra Mor	172.4	34,763	484,004	623,450
3	Rawalpindi GT Road 26 No Interchange	400.3	109,990	2,575,157	4,826,571
4	Do-Minimum Scenario at G-13 Chowk	390.2	72,346	1,678,921	3,309,820
5	Do-Something Scenario at Golra Mor	120.6	17,564	421,674	574,321

4.2.3.2 Graphs of 100 percent Traffic

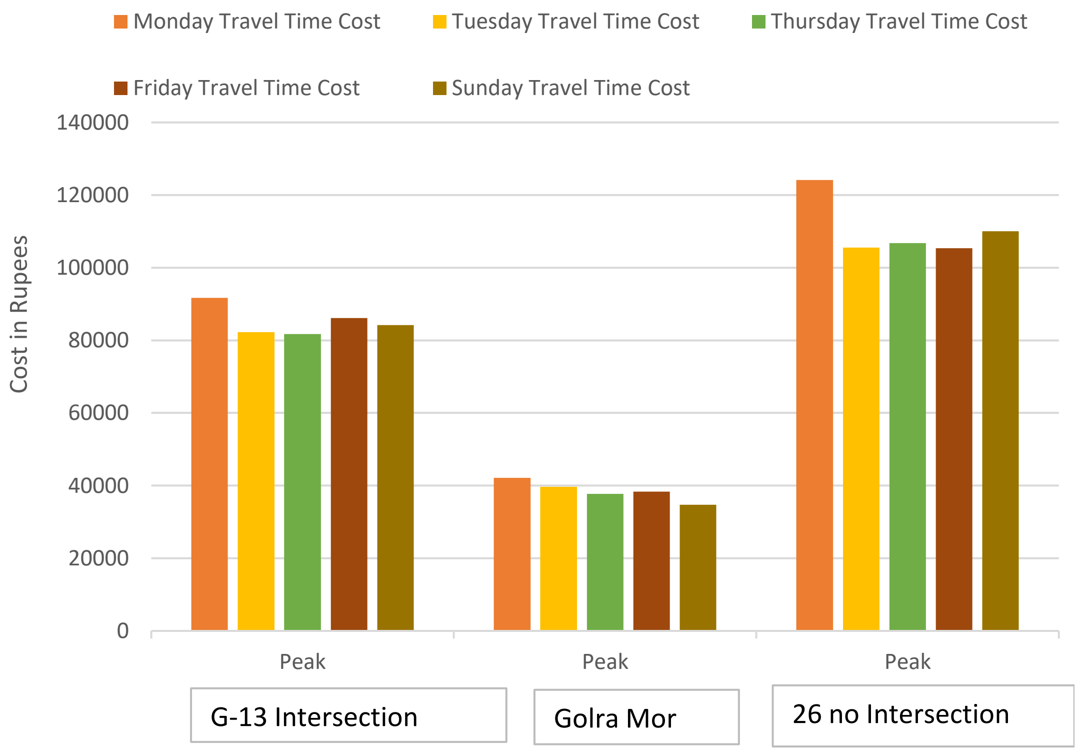

Figure 4-10: 100% Imposed Traffic Data Travel Time Cost

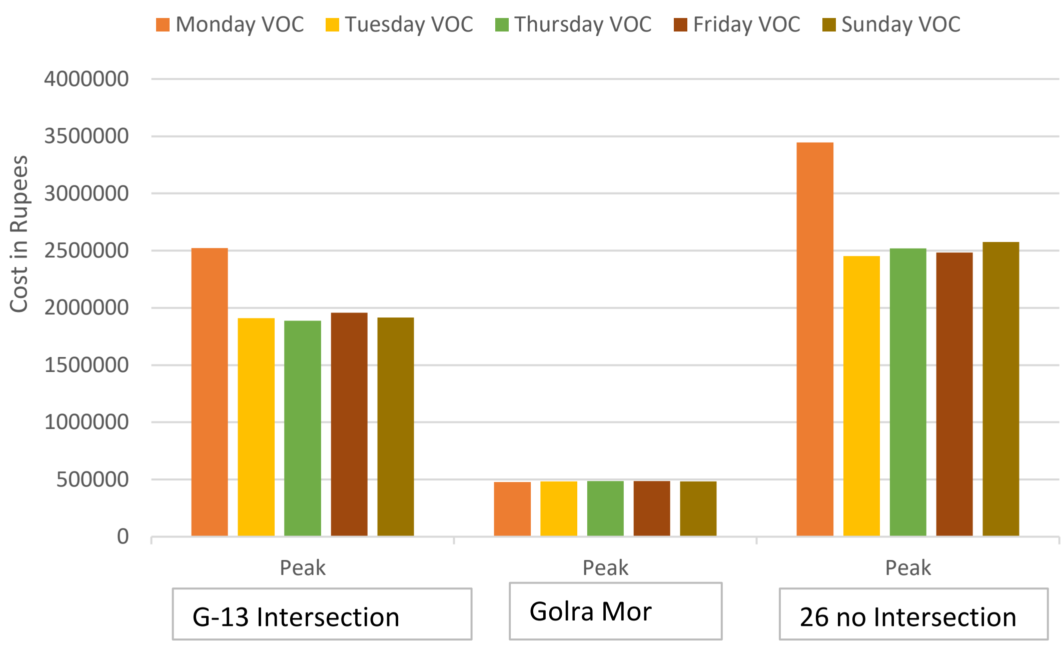

Figure 4-11: 100% Imposed Traffic Data VOC according to NTRC Model

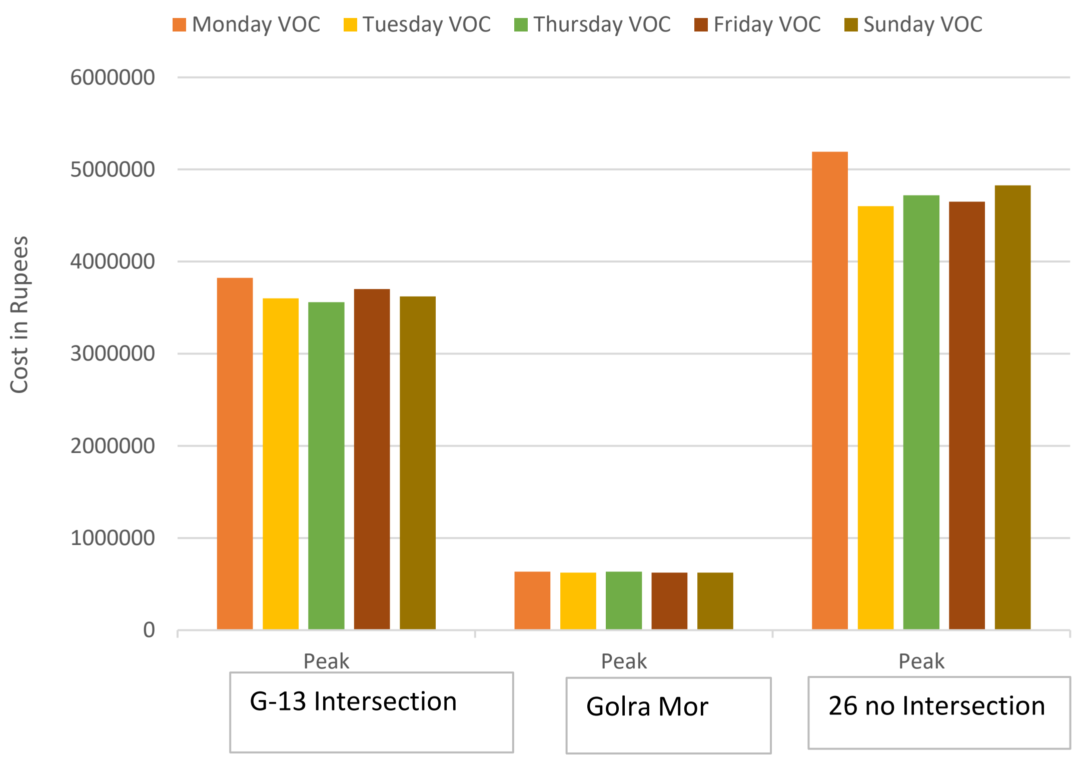

Figure 4-12: 100% Imposed Traffic Data VOC according to Hepburn Model

4.3 Mitigation Strategies for Future

Two mitigation strategies for future as followed at two intersections. At G-13 intersection, lane addition and at Golra Mor interchange provision is assumed. After the application of these strategies, a comparative study before and after has been done. There is significant change in parameters due to lane addition or interchange provision. The graphs at 4.3.1 and 4.3.2 clearly show the difference of all parameters.

4.3.1 Lane Addition

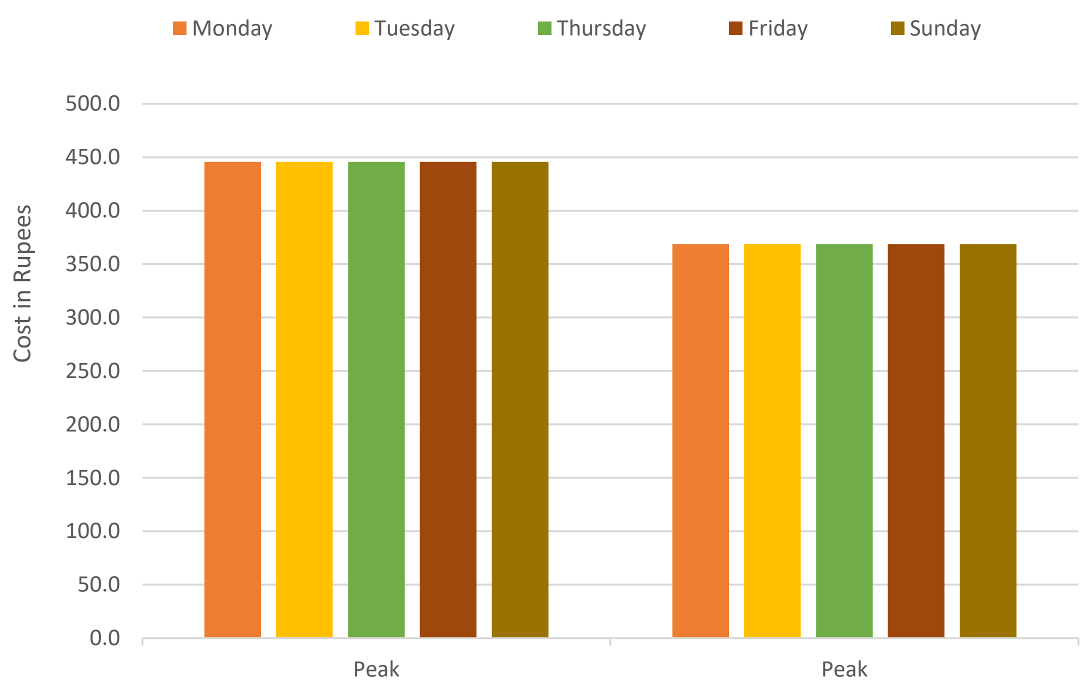

Figure 4-13: Comparison of Travel Time at G-13 intersection before and after Lane Provision

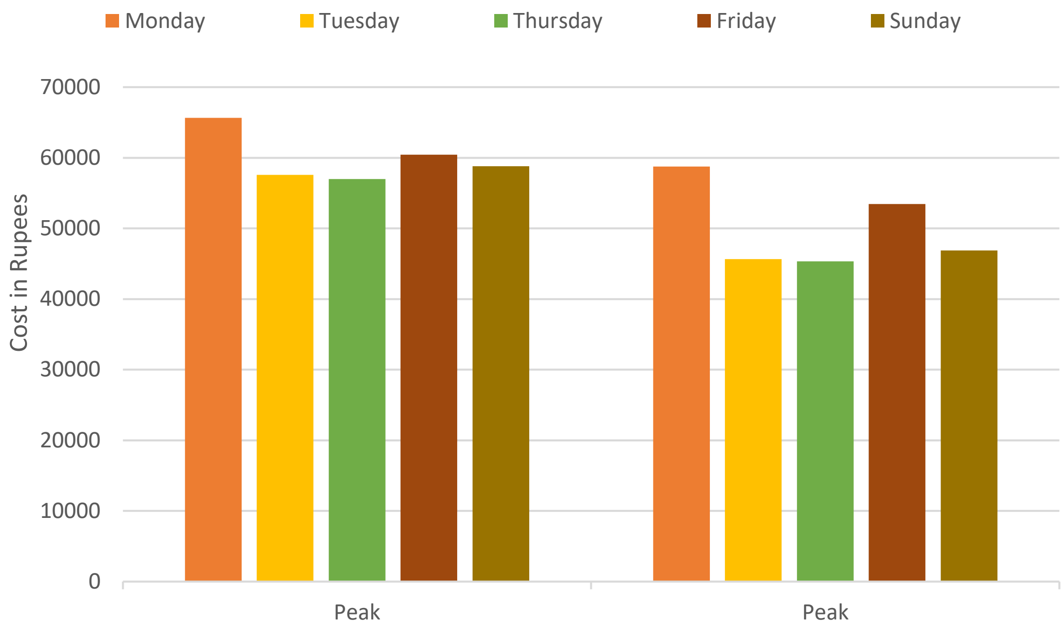

Figure 4-14: Comparison of Travel Time Cost at G-13 intersection before and after Lane provision

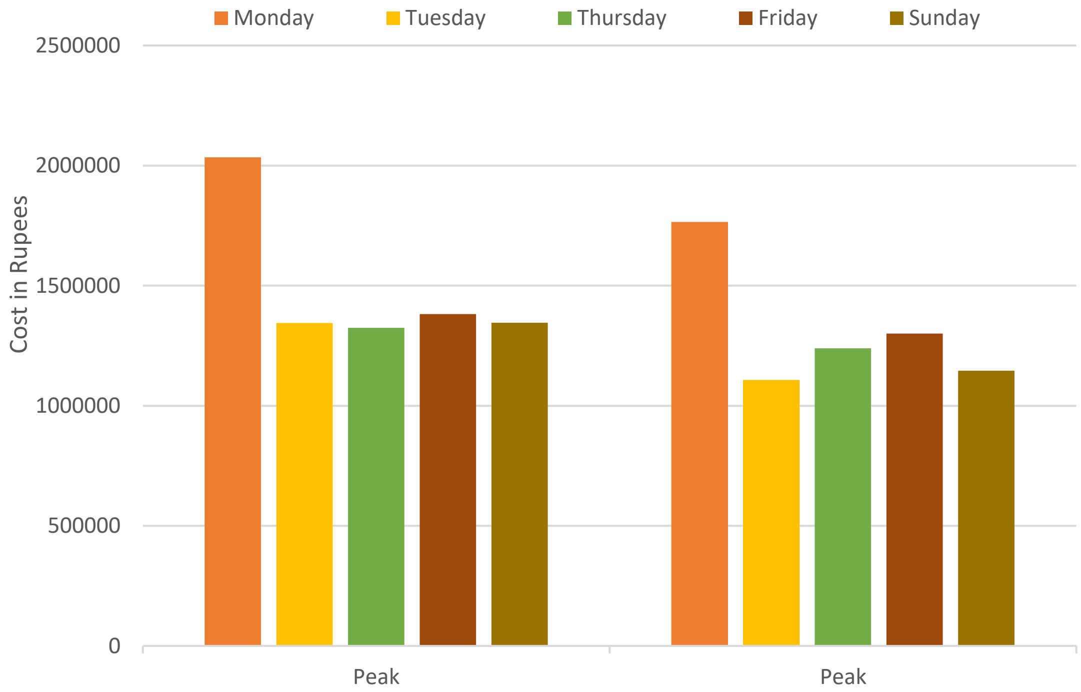

Figure 4-15: Comparison of VOC according to NTRC Model before and after lane provision at G-13 Intersection

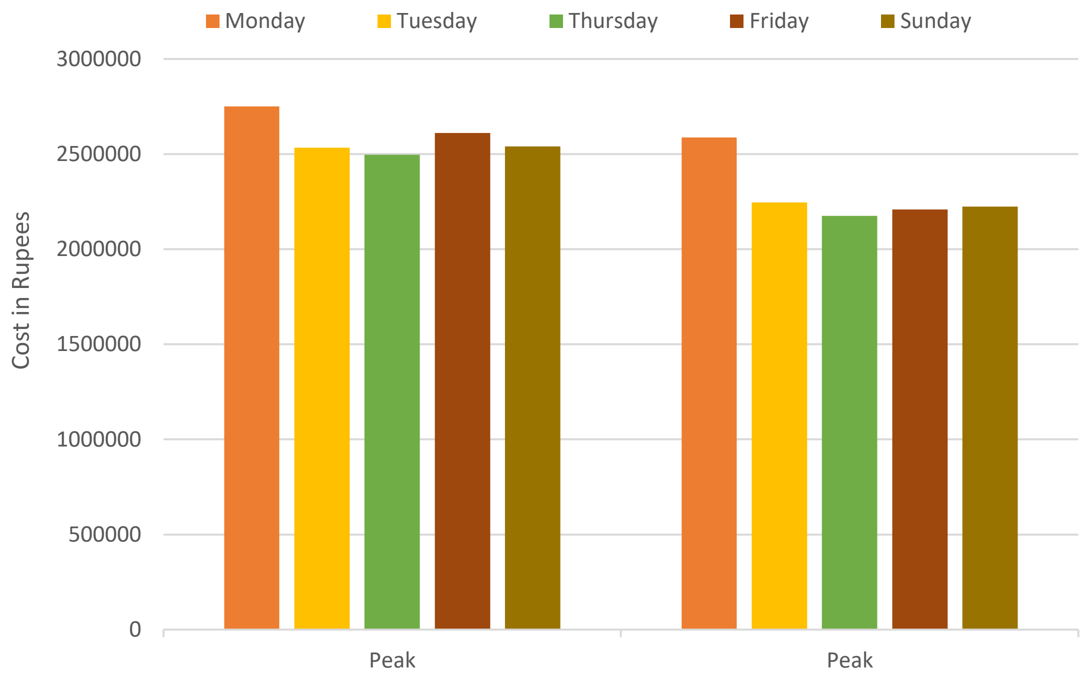

Figure 4-16: Comparison of VOC according to Hepburn Model before and after lane provision at G-13 Intersection

4.3.2 Interchange Provision

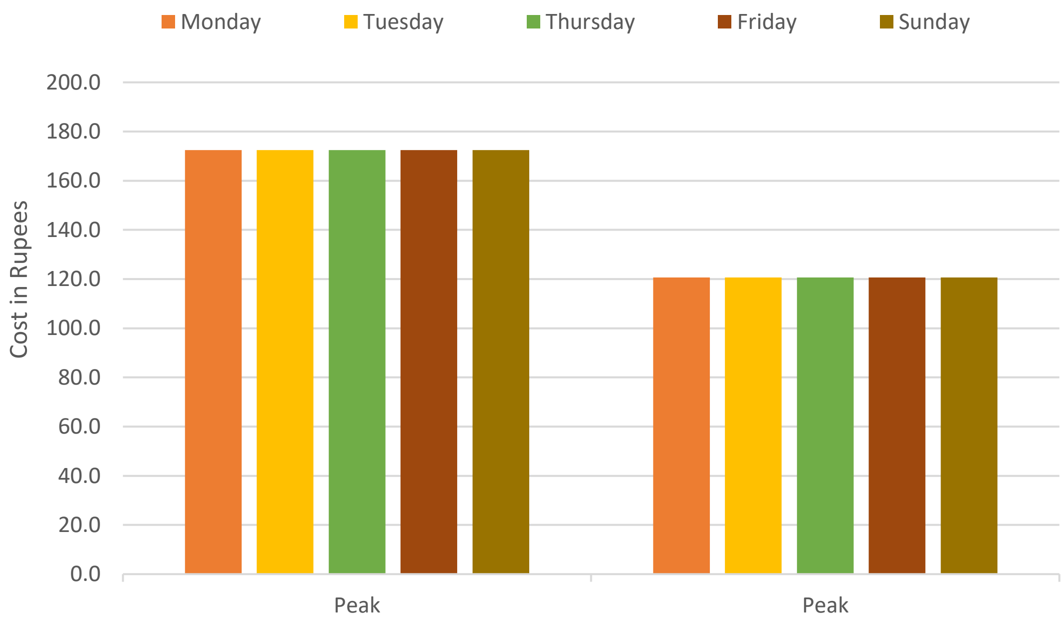

Figure 4-17: Comparison of Travel Time at Golra Mor before and after Interchange Provision

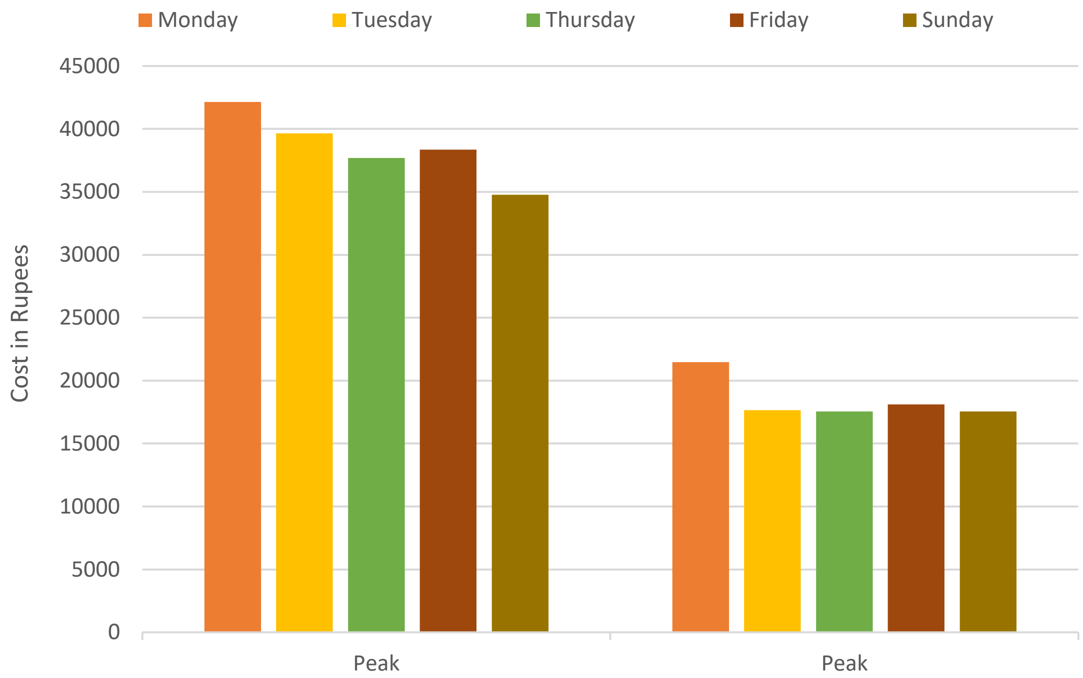

Figure 4-18: Comparison of Travel Time Cost at Golra Mor before and after Interchange Provision

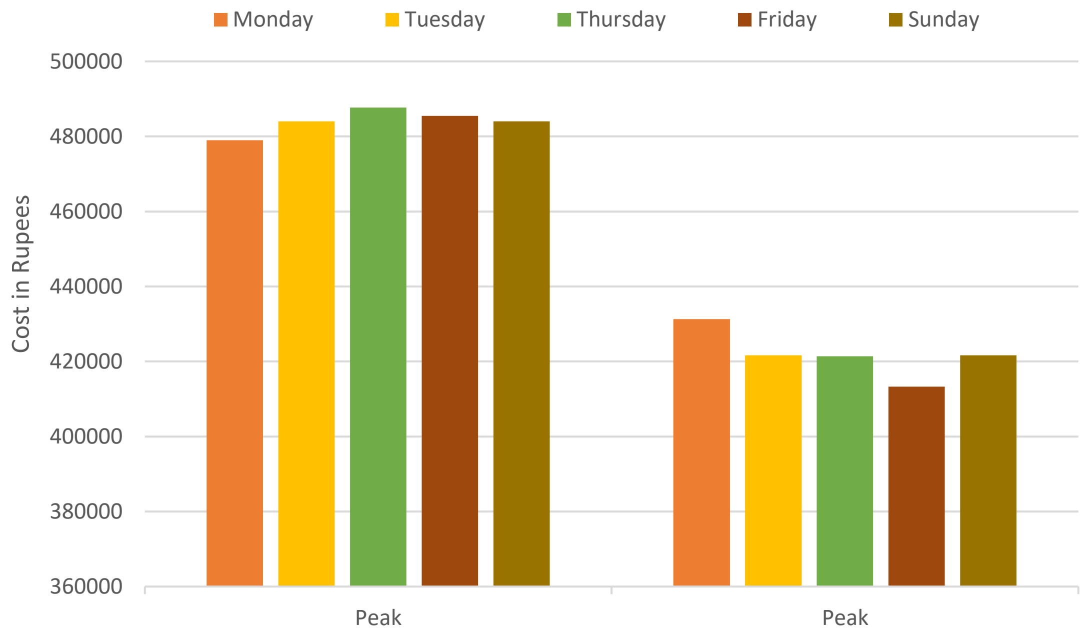

Figure 4-19: Comparison of VOC according to NTRC Model at Golra Mor before and after Interchange Provision at Golra Mor

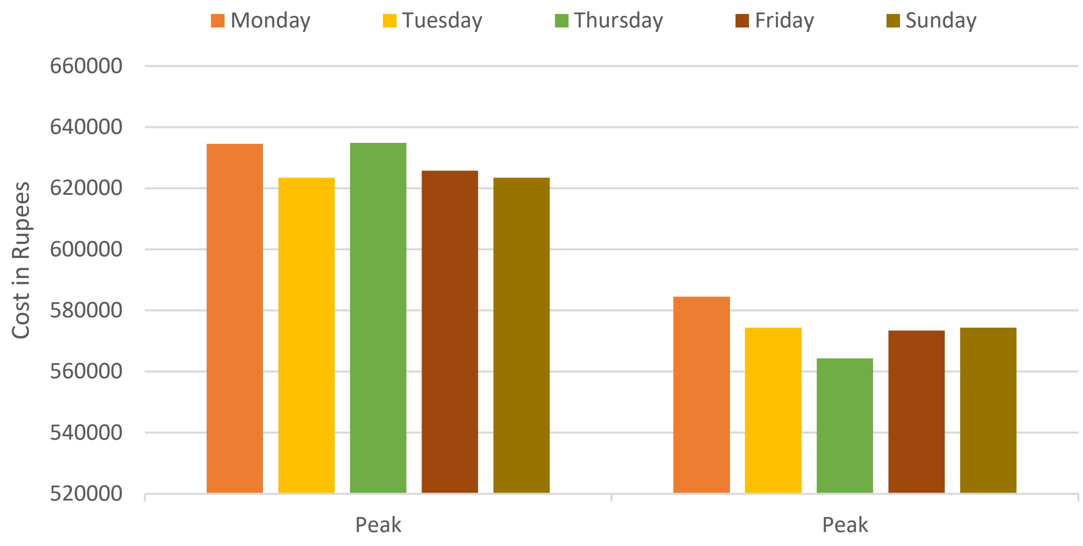

Figure 4-20: Comparison of VOC according to Hepburn Model at Golra Mor before and after Interchange Provision

These graphical representations of above-mentioned results are generated from the analysis outcome of Synchro models that we have developed for current, do-nothing, and mitigation strategies scenarios. The outcome of the models is attached as annexures.

4.4 Level of Service

Level of Service is a term qualitatively describe the operating roadway conditions based on factors such as speed, travel time, maneuverability, and delay.

Table 4-25: LOS for G-13 Intersection

S./No.	Scenario	ICU* Level of Service	ICU*
1	Current Scenario	B	63.6%
2	30% Development	B	63.6%
3	65% Development	F	120.3%
4	100% Development	H	148.7%
5	Mitigation Measure	E	97.2%

Note: ICU* stands for Intersection Capacity Utilization according to HCM 2010.

Table 4-26: LOS for 26 No Intersection

S./No.	Scenario	ICU* Level of Service	ICU*
1	Current Scenario	C	67.1%
2	30% Development	F	93.4%
3	65% Development	H	112.3%
4	100% Development	H	164.8%

Note: ICU* stands for Intersection Capacity Utilization according to HCM 2010.

Table 4-27: LOS for Golra Mor

S/No.	Scenario	ICU* Level of Service	ICU*
1	Current Scenario	H	127.6%
2	30% Development	H	188.8%
3	65% Development	H	222.4%
4	100% Development	H	318.7%
5	Mitigation Measure	H	142.9%

Note: ICU* stands for Intersection Capacity Utilization according to HCM 2010.

4.5 Discussions

These tables and graphs clearly depict the current and proposed development traffic volume increase and its effect on the parameters i.e., increase in travel time, travel time cost, vehicle operating cost of both models.

The traffic volume doesn't vary much with days. There is not a much difference in travel time. The graphs of travel time are enclosed as annexures. For every intersection, travel time of current scenario differs with travel time of do-nothing scenario. Moreover, in do-nothing scenario travel time among 30% and 65% and 100% development also differs a lot. Moreover, with proposed mitigation measures, travel time at G-13 intersection and Golra Mor decreases. The travel time at G-13 and Golra Mor intersection decreases by almost 70, and 40-50 seconds.

Graph of cost for travel time for all current, do-nothing scenarios clearly shows an increase with an increase in traffic volumes. While doing lane addition at Golra Interchange/G-13 chowk, we have observed a significant change in reduction of travel cost. The same we have noticed while considering interchange provision at Golra Mor location. While at the interchange of 26 number located the GT road, the cost observed as the highest among the rest of the two studied junctions. It implies that at the peak time of congestion on the Golra Mor and G-13 intersections has greater influence on the 26 number location. Therefore, the mitigation measures adopted at G-13 and Golra Mor could favor in less cost as compared to the current (do-nothing) scenario. This need to study while considering another study based on the network level optimization.

We have determined Vehicle Operating Cost (VOC) through two (2) methods (e.g. Hepburn Model, and NTRC study model). The cost (in terms of vehicle per kilometers) according to Hepburn Model is more than of NTRC Model. Similar to the travel time cost, the VOC for the 26 number location on the GT road has observed as higher cost than to other intersections which is followed by the Golra Interchange/ G-13 Chowk and lastly the Golra Mor intersection. However, there is reduction in cost over location where we have proposed mitigation strategies.

Through the HCM model, we have determined the Intersection Capacity Utilization (ICU) percentages as well. The percentage illustrates the value based on the results obtained from the travel time (i.e. congestion) analysis.

CHAPTER 5: CONCLUSION

This study has concluded in the adverse traffic congestion would arise with a significant increase in impact from the housing societies development on the study area intersections. It reflects that there will be increase in the peak hour congestion to further level We have dealt with by introducing hard interventions (i.e., lane addition and interchange provision) as mitigation strategies and found as a suitable solution (achieving less ICU percentage) to cope congestion. However, it is pertinent to mentioned that such solo hard interventions are not providing solution that is long lasting until and unless some other measures emphasis on model shift to be introduced. It is said so because the introducing more supply in urbanized area will ultimately result in increase in demand as per traffic theory. Therefore, it is vital for the government to look into this matter while proposing and adopting techniques to mitigate traffic congestion. A sustainable way is to subsequently look into provision of public transport modes schemes focusing on enhancing mode shift. Only provision of improved public transport schemes for the existing public transport users/ commuters could not resolve the traffic congestion on the road network and thus need a holistic approach to handle traffic generated from the future developments.

RECOMMENDATIONS AND LIMITATIONS

The first recommendation is that instead of using Synchro, Vissim should be used for traffic simulation which is an advanced software and has much more applications than Synchro.

Furthermore, this study was confined to intersections, it can be expanded for networks (links) as well. Furthermore, a detailed study may be conducted in this concern for the development of a traffic plan for future traffic volume due to developments and population growth as well.

The limitation of this research study is that ITE trip rates were used for trip generation from new housing societies. These trip rates are not feasible to Pakistani circumstances. If trip rates are converted according to Pakistani situation, then better results can be acquired.

Hepburn model was used for calculation of vehicle operating cost. The coefficients of this model are not fitting to Pakistani conditions. May these be first converted according to Pakistani standards and then their usage will be feasible to calculate VOC for vehicles in Pakistan.

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ANNEXURE

Annx Table 1: Housing Societies Data

S/No.	Description	No. of Plots						
	Plots Sizes	**Top City**	**Airport Green Garden**	**Gandhara City**	**Elite Reverie Housing Society**	**Taj Residencia Extension**	**Faisal Town**	**Pakistan Employees Co-operative Housing Society**
1.	100 * 180	51						
2.	45 x 200				124			
3.	90 x 120							14
4.	90 x 110		6					
5.	90 x 100				128			
6.	90 x 80						6	
7.	100 x 60						2	
8.	80 x 110		27					
9.	75 * 120	170				107		
10.	75 x 100							24
11.	70 x 60						3	
12.	60 x 130					4		
13.	60 x 90		4			2		107
14.	60 x 80					2		

15.	60 x 60						3	
16.	50 * 90	2419	217	20	271	135	249	50
17.	50 x 80					10		
18.	55 x 65						1	
19.	50 x 60						27	
20.	50 x 65						14	
21.	40 x 80					104	296	
22.	45 x 60						4	
23.	45 x 65							
24.	40 x 75			14				
25.	40 x 70						12	
26.	40 x 65		42					
27.	40 x 60						66	
28.	40 x 40						6	
29.	35 x 70					455	657	299
30.	35 * 65	2805	935					
31.	35 x 60						6	
32.	30 x 70			36				493
33.	30 x 60		803	180		183	3473	359

34.	30 x 55						4	
35.	30 x 50		36				6	
36.	30 x 40					12		
37.	25 x 90				512			
38.	25 x 60						23	
39.	25 * 50	1039	3054	95		515	1285	772
40.	25 * 45				262			
41.	Apartments	46		5		10 (93.27K)		9
42.	Commercial						5%	116

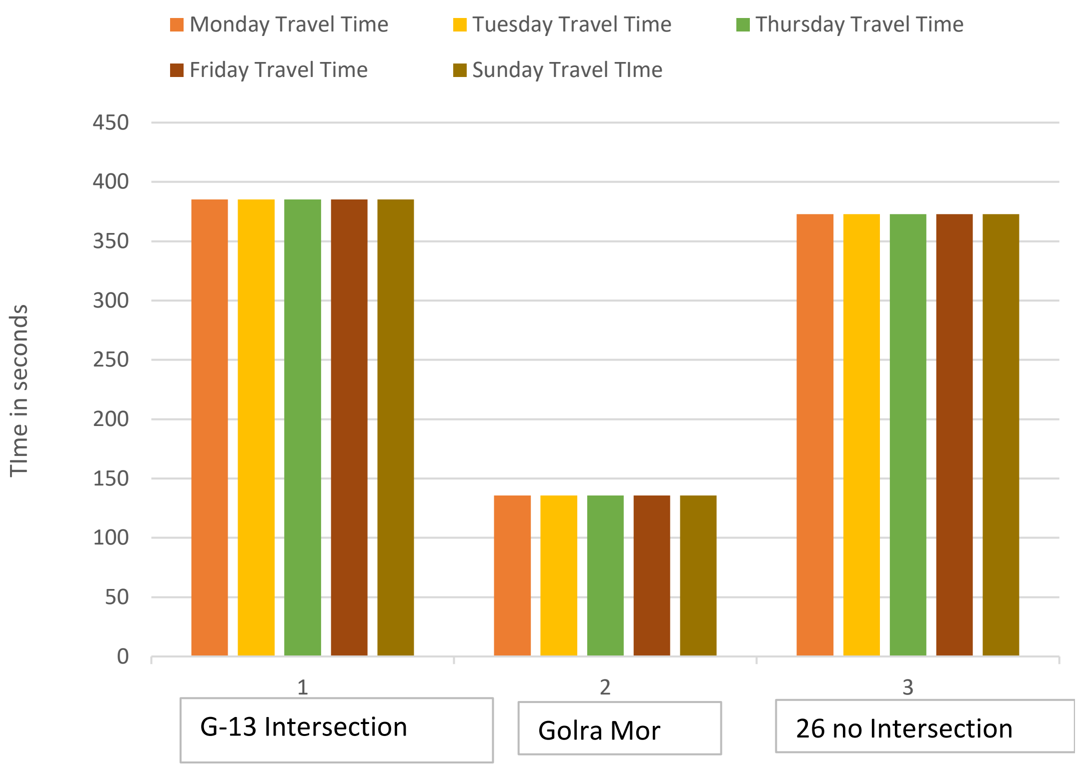
Annx Table 2: Housing Societies Data

S/No.	**Description**	**No. of Plots**					
	Plots Sizes	**Faisal Hills**	**Khudadad City**	**Multi Gardens B-17**	**Faisal Margalla City**	**Marble Arch Enclave**	**Taj Residentia**
1.	100 * 180						
2.	45 x 200						
3.	90 x 120						
4.	90 x 110						

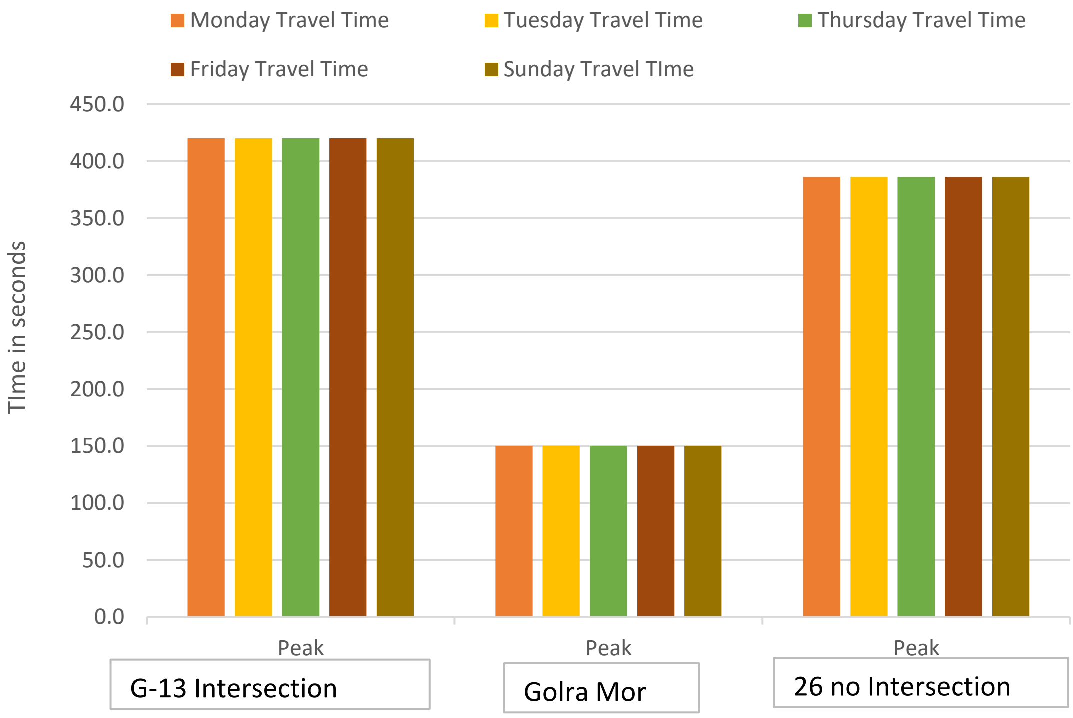
5.	90 x 100						
6.	90 x 80						
7.	100 x 60						
8.	80 x 125			21			
9.	80 x 120	30					
10.	80 x 110			65			
11.	75 * 120	279		28			
12.	70 x 120	6					
13.	75 x 100					1	
14.	70 x 60						
15.	60 x 130						
16.	60 x 120		13			38	52
17.	60 x 90	41		355		6	
18.	60 x 80						
19.	60 x 60						
20.	50 * 90	713	175	4071	207		
21.	50 x 80						
22.	55 x 65						
23.	50 x 60					2	

24.	50 x 65						
25.	45 x 80	32			4	109	
26.	40 x 80	617		1105	377		
27.	45 x 60					16	
28.	45 x 65						
29.	40 x 75					30	
30.	40 x 70	12		35	16	381	
31.	40 x 65						
32.	40 x 60	14		81	22	2	5
33.	40 x 40					120	64
34.	35 x 70	1584		2398	585		
35.	35 * 65		141	306		36	
36.	35 x 60			21		10	
37.	30 x 70						
38.	30 x 60	2198	191	7228	1362		
39.	35 x 55	4				1105	139
40.	30 x 55						
41.	30 x 50	245			26		
42.	30 x 40					5%	

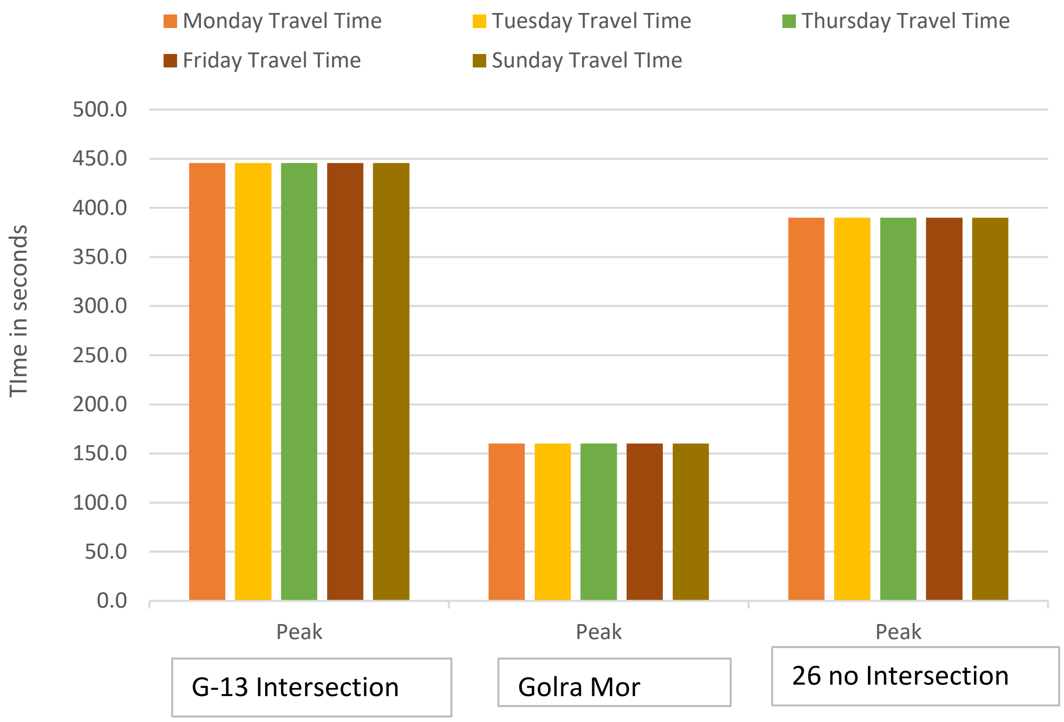
43.	25 x 90						
44.	25 x 60			8			
45.	25 * 50	7075		2241	1363		
46.	25 * 45		434				
47.	20 x 45			135			
48.	Apartments						
49.	Commercial						



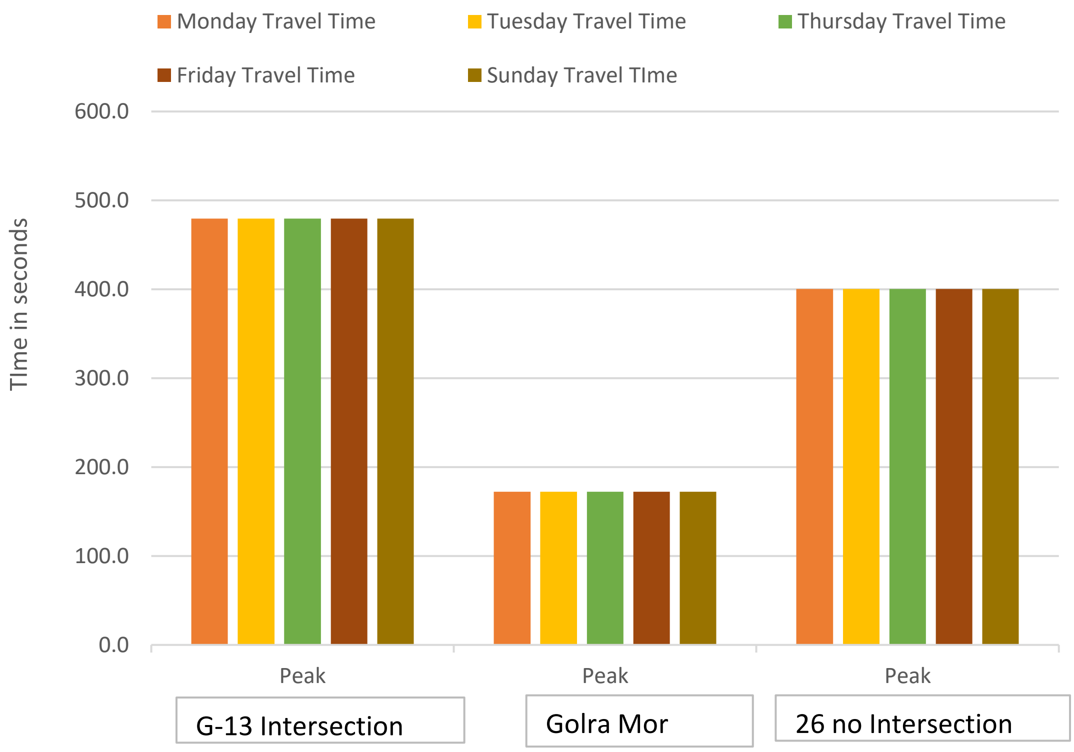
Annx Figure 1: Travel Time of Current Data



Annx Figure 2: Travel Time of 30% Imposed Traffic Data



Annx Figure 3: Travel Time of 65% Imposed Data



Annx Figure 4: Travel Time of 100% Imposed Traffic Data

Annx Table 3: Tuesday Peak Hour Current Data

Intersection	**Peak Hour**	**East Bound**				**West Bound**				**North Bound**				**South Bound**			
		R	T	L1	L2	R	T	L1	L2	R	T	L1	L2	R	T	L1	L2
G-13 Interchange	am	-	3961	425	150	-	3330	814	185	-	978	339	161	-	562	339	146
	pm	-	3675	447	89	-	3708	898	123	-	823	283	167	-	477	363	121
Golra Mor	am	-	2997	1259	0	-	3147	519	0	-	0	450	0	-	0	1105	0
	pm	-	2846	1072	0	-	2977	455	0	-	0	402	0	-	0	705	0
26 No Interchange	am	-	2057	1099	145	-	2023	953	155	-	1984	870	0	-	1691	632	0
	pm	-	2145	1179	135	-	2051	926	145	-	2018	910	0	-	1887	763	0

Annx Table 4: Tuesday Peak Hour 30% Imposed Data

Intersection	**Peak Hour**	**East Bound**				**West Bound**				**North Bound**				**South Bound**			
		R	T	L1	L2	R	T	L1	L2	R	T	L1	L2	R	T	L1	L2
G-13 Interchange	am	-	6279	683	195	-	5290	1304	240	-	1536	535	209	-	874	530	190
	pm	-	5921	725	116	-	5962	1427	160	-	1302	451	217	-	772	586	157
Golra Mor	am	-	4736	2004	0	-	4998	820	0	-	0	726	0	-	0	1767	0
	pm	-	4572	1710	0	-	4810	729	0	-	0	659	0	-	0	1116	0
26 No Interchange	am	-	3269	1752	188	-	3201	1507	201	-	3150	1370	0	-	2712	1010	0
	pm	-	3427	1869	175	-	3266	1472	188	-	3233	1456	0	-	2987	1212	0

Annx Table 5: Tuesday Peak Hour 65% Imposed Data

Intersection	Peak Hour	East Bound				West Bound				North Bound				South Bound			
		R	T	L1	L2	R	T	L1	L2	R	T	L1	L2	R	T	L1	L2
G-13 Interchange	am	-	6829	744	247	-	5755	1420	305	-	1668	581	265	-	947	575	240
	pm	-	6454	791	146	-	6497	1552	202	-	1416	491	275	-	842	638	199
Golra Mor	am	-	5148	2181	0	-	5438	892	0	-	0	791	0	-	0	1925	0
	pm	-	4981	1862	0	-	5245	794	0	-	0	720	0	-	0	1214	0
26 No Interchange	am	-	3557	1907	239	-	3480	1639	255	-	3426	1488	0	-	2955	1099	0
	pm	-	3731	2033	222	-	3554	1601	239	-	3521	1585	0	-	3248	1319	0

Annx Table 6: Tuesday Peak Hour 100% Imposed Data

Intersection	Peak Hour	East Bound				West Bound				North Bound				South Bound			
		R	T	L1	L2	R	T	L1	L2	R	T	L1	L2	R	T	L1	L2
G-13 Interchange	am	-	9822	1076	300	-	8286	2053	370	-	2388	835	322	-	1350	822	292
	pm	-	9355	1149	178	-	9408	2235	246	-	2034	708	334	-	1223	926	242
Golra Mor	am	-	7394	3143	0	-	7829	1281	0	-	0	1148	0	-	0	2780	0
	pm	-	7210	2686	0	-	7613	1148	0	-	0	1052	0	-	0	1745	0
26 No Interchange	am	-	5123	2750	290	-	5001	2355	310	-	4932	2133	0	-	4274	1587	0
	pm	-	5386	2924	270	-	5123	2306	290	-	5090	2290	0	-	4669	1899	0

Annx Table 7: Thursday Peak Hour Current Data

Intersection	Peak Hour	East Bound				West Bound				North Bound				South Bound			
		R	T	L1	L2	R	T	L1	L2	R	T	L1	L2	R	T	L1	L2
G-13 Interchange	am	-	3950	454	150	-	3337	897	158	-	874	313	144	-	483	301	102
	pm	-	3230	421	90	-	3621	770	175	-	765	223	152	-	556	239	109
Golra Mor	am	-	2923	1199	0	-	2841	434	0	-	0	388	0	-	0	1256	0
	pm	-	2803	891	0	-	2648	419	0	-	0	367	0	-	0	1136	0
26 No Interchange	am	-	1971	1129	165	-	1926	1183	166	-	2094	754	0	-	1635	753	0
	pm	-	2071	1126	162	-	1981	1159	187	-	1982	717	0	-	1648	724	0

Annx Table 8: Thursday Peak Hour 30% Imposed Data

Intersection	Peak Hour	East Bound				West Bound				North Bound				South Bound			
		R	T	L1	L2	R	T	L1	L2	R	T	L1	L2	R	T	L1	L2
G-13 Interchange	am	-	6324	718	195	-	5322	1425	205	-	1385	493	187	-	756	468	132
	pm	-	5213	691	117	-	5868	1263	227	-	1234	363	197	-	897	385	141
Golra Mor	am	-	4664	1910	0	-	4510	683	0	-	0	601	0	-	0	2002	0
	pm	-	4561	1446	0	-	4283	685	0	-	0	573	0	-	0	1855	0
26 No Interchange	am	-	3155	1795	214	-	3073	1886	215	-	3362	1199	0	-	2613	1213	0
	pm	-	3387	1835	210	-	3257	1908	243	-	3249	1186	0	-	2696	1195	0

Annx Table 9: Thursday Peak Hour 65% Imposed Data

Intersection	Peak Hour	East Bound				West Bound				North Bound				South Bound			
		R	T	L1	L2	R	T	L1	L2	R	T	L1	L2	R	T	L1	L2
G-13 Interchange	am	-	6888	780	247	-	5793	1550	260	-	1507	535	236	-	820	508	168
	pm	-	5684	756	148	-	6402	1380	288	-	1345	396	250	-	978	420	179
Golra Mor	am	-	5077	2079	0	-	4906	743	0	-	0	652	0	-	0	2179	0
	pm	-	4978	1578	0	-	4671	748	0	-	0	621	0	-	0	2026	0
26 No Interchange	am	-	3436	1953	272	-	3345	2053	273	-	3662	1305	0	-	2846	1323	0
	pm	-	3700	2003	267	-	3560	2086	308	-	3550	1297	0	-	2945	1307	0

Annx Table 10: Thursday Peak Hour 100% Imposed Data

Intersection	Peak Hour	East Bound				West Bound				North Bound				South Bound			
		R	T	L1	L2	R	T	L1	L2	R	T	L1	L2	R	T	L1	L2
G-13 Interchange	am	-	9954	1121	300	-	8356	2231	316	-	2167	767	288	-	1172	724	204
	pm	-	8245	1105	180	-	9305	2018	350	-	1951	577	304	-	1419	609	218
Golra Mor	am	-	7325	2997	0	-	7062	1065	0	-	0	927	0	-	0	3143	0
	pm	-	7248	2295	0	-	6783	1092	0	-	0	887	0	-	0	2955	0
26 No Interchange	am	-	4965	2813	320	-	4827	2961	332	-	5300	1880	0	-	4109	1917	0
	pm	-	5400	2918	334	-	5207	3054	374	-	5187	1902	0	-	4298	1915	0

Annx Table 11: Friday Peak Hour Current Data

Intersection	Peak Hour	East Bound				West Bound				North Bound				South Bound			
		R	T	L1	L2	R	T	L1	L2	R	T	L1	L2	R	T	L1	L2
G-13 Interchange	am	-	3990	472	190	-	4079	754	150	-	845	314	145	-	532	304	136
	pm	-	3450	477	135	-	4119	829	166	-	748	271	171	-	575	332	153
Golra Mor	am	-	3005	1141	0	-	3190	437	0	-	0	401	0	-	0	1056	0
	pm	-	2740	994	0	-	3125	440	0	-	0	405	0	-	0	1256	0
26 No Interchange	am	-	2038	1130	139	-	2117	1021	125	-	1894	903	0	-	1723	798	0
	pm	-	1974	1204	152	-	2172	1297	171	-	2149	889	0	-	2062	776	0

Annx Table 12: Friday Peak Hour 30% Imposed Data

Intersection	Peak Hour	East Bound				West Bound				North Bound				South Bound			
		R	T	L1	L2	R	T	L1	L2	R	T	L1	L2	R	T	L1	L2
G-13 Interchange	am	-	6294	757	247	-	6416	1199	195	-	1317	489	188	-	822	467	176
	pm	-	5440	748	175	-	6517	1320	215	-	1161	424	222	-	892	518	199
Golra Mor	am	-	4732	1812	0	-	5019	686	0	-	0	614	0	-	0	1642	0
	pm	-	4316	1577	0	-	4934	687	0	-	0	662	0	-	0	1975	0
26 No Interchange	am	-	3189	1778	180	-	3322	1615	162	-	2981	1415	0	-	2720	1267	0
	pm	-	3095	1891	197	-	3448	2046	222	-	3381	1392	0	-	3276	1225	0

Annx Table 13: Friday Peak Hour 65% Imposed Data

Intersection	**Peak Hour**	**East Bound**				**West Bound**				**North Bound**				**South Bound**			
		R	T	L1	L2	R	T	L1	L2	R	T	L1	L2	R	T	L1	L2
G-13 Interchange	am	-	6840	824	313	-	6971	1305	247	-	1430	530	239	-	891	506	224
	pm	-	5912	995	222	-	7086	1437	273	-	1259	460	282	-	967	562	252
Golra Mor	am	-	5141	1972	0	-	5463	746	0	-	0	665	0	-	0	1781	0
	pm	-	4690	1715	0	-	5363	745	0	-	0	723	0	-	0	2146	0
26 No Interchange	am	-	3462	1931	229	-	3608	1755	206	-	3239	1536	0	-	2956	1378	0
	pm	-	3361	2054	250	-	3751	2224	282	-	3674	1512	0	-	3565	1332	0

Annx Table 14: Friday Peak Hour 100% Imposed Data

Intersection	**Peak Hour**	**East Bound**				**West Bound**				**North Bound**				**South Bound**			
		R	T	L1	L2	R	T	L1	L2	R	T	L1	L2	R	T	L1	L2
G-13 Interchange	am	-	9816	1192	380	-	9990	1880	300	-	2040	756	290	-	1265	716	272
	pm	-	8482	1163	270	-	10183	2071	332	-	1792	657	342	-	1376	802	306
Golra Mor	am	-	7372	2839	0	-	7815	1068	0	-	0	940	0	-	0	2538	0
	pm	-	6725	2468	0	-	7700	1064	0	-	0	1055	0	-	0	3075	0
26 No Interchange	am	-	4949	2767	278	-	5165	2522	250	-	4643	2197	0	-	4243	1984	0
	pm	-	4809	2942	304	-	5398	3192	342	-	5266	2162	0	-	5133	1912	0

Annx Table 15: Sunday Peak Hour Current Data

Intersection	Peak Hour	East Bound				West Bound				North Bound				South Bound			
		R	T	L1	L2	R	T	L1	L2	R	T	L1	L2	R	T	L1	L2
G-13 Interchange	am	-	3943	521	200	-	3758	681	195	-	776	231	125	-	590	304	121
	pm	-	4249	633	150	-	3884	770	165	-	776	268	136	-	583	318	111
Golra Mor	am	-	2702	918	0	-	2647	470	0	-	0	455	0	-	0	998	0
	pm	-	2846	1002	0	-	2587	465	0	-	0	445	0	-	0	1235	0
26 No Interchange	am	-	2260	1101	157	-	2126	1169	174	-	1735	720	0	-	1766	775	0
	pm	-	2401	1178	159	-	2269	1499	155	-	1824	795	0	-	2222	741	0

Annx Table 16: Sunday Peak Hour 30% Imposed Data

Intersection	Peak Hour	East Bound				West Bound				North Bound				South Bound			
		R	T	L1	L2	R	T	L1	L2	R	T	L1	L2	R	T	L1	L2
G-13 Interchange	am	-	6278	839	260	-	6013	1079	253	-	1224	365	162	-	932	480	157
	pm	-	6670	995	195	-	6086	1221	214	-	1207	419	178	-	920	499	144
Golra Mor	am	-	4335	1462	0	-	4245	752	0	-	0	752	0	-	0	1592	0
	pm	-	4430	1559	0	-	4043	722	0	-	0	683	0	-	0	1901	0
26 No Interchange	am	-	3628	1775	204	-	3408	1859	226	-	2785	1149	0	-	2851	1240	0
	pm	-	3758	1846	206	-	3527	2338	201	-	2837	1229	0	-	3470	1157	0

Annx Table 17: Sunday Peak Hour 65% Imposed Data

Intersection	Peak Hour	East Bound				West Bound				North Bound				South Bound			
		R	T	L1	L2	R	T	L1	L2	R	T	L1	L2	R	T	L1	L2
G-13 Interchange	am	-	6832	915	330	-	6548	1173	321	-	1331	397	206	-	1013	522	199
	pm	-	7244	1081	247	-	6609	1328	272	-	1309	455	224	-	999	542	183
Golra Mor	am	-	4723	1592	0	-	4625	819	0	-	0	822	0	-	0	1733	0
	pm	-	4807	1691	0	-	4389	783	0	-	0	739	0	-	0	2059	0
26 No Interchange	am	-	3953	1935	259	-	3712	2023	287	-	3034	1251	0	-	3108	1350	0
	pm	-	4080	2005	262	-	3826	2537	255	-	3077	1332	0	-	3766	1256	0

Annx Table 18: Sunday Peak Hour 100% Imposed Data

Intersection	Peak Hour	East Bound				West Bound				North Bound				South Bound			
		R	T	L1	L2	R	T	L1	L2	R	T	L1	L2	R	T	L1	L2
G-13 Interchange	am	-	9848	1326	400	-	9461	1687	390	-	1910	570	250	-	1454	749	242
	pm	-	10371	1548	300	-	9453	1911	330	-	1866	651	272	-	1434	776	222
Golra Mor	am	-	6832	2295	0	-	6689	1183	0	-	0	1206	0	-	0	2500	0
	pm	-	6853	2410	0	-	6269	1115	0	-	0	1047	0	-	0	2920	0
26 No Interchange	am	-	5720	2805	318	-	5367	2914	348	-	4390	1805	0	-	4509	1950	0
	pm	-	5832	2868	314	-	5452	3621	310	-	4385	1892	0	-	5377	1793	0