The Impact of VIP Movements on Urban Traffic in Pakistan

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DEDICATION

To my parents and siblings, who encouraged and supported me in every aspect of life.

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ABSTRACT

Urban non-recurrent congestion caused by the movement of important individuals (e.g., high-level government officials, foreign delegates, and international sports teams) is a common practice in developing countries. This study employs a combination of discrete choice modeling and micro-simulation to examine the effects of such congestion on the environment and economy in developing countries, with a specific focus on Pakistan as a representative case. To achieve this, choice data was collected through a questionnaire-based survey, while traffic counts were conducted at five major blockade locations in Rawalpindi and Islamabad, Pakistan. These data sets were modeled using the R language and PTV Vissim software to estimate the value of time and measure the impact of road blockages on various performance measures, including fuel consumption, travel time, and exhaust emissions. The study estimated the value of time to be 6.60 Rs/min through an unordered choice model (multinomial logit model). Additionally, income and gender were identified as significant factors influencing respondents' mode choices. The findings further highlight that road blockages exceeding two minutes significantly amplify the negative impacts on both the environment and the economy.

Keywords: Urban Traffic Congestion, Planned Special Events, Discrete Choice Modelling, Microsimulation, Utility Model, Value of Time.

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LIST OF ABBREVIATIONS

Abb.	Description
VIP	Very Important Personals
PSE	Planned Special Events
SP	Stated Preference
RP	Revealed Preference
DCM	Discrete Choice Modelling
VOT	Value of Time
LOS	Level of Service
LLRT	Log-Likelihood Ratio Test
AIC	Akaike Information Criterion
BIC	Bayesian Information Criterion
VOC	Volatile Organic Compounds
CO	Carbon Monoxide
NOx	Nitrogen Oxides

CHAPTER 1: INTRODUCTION

Urban non-recurrent congestion caused by the movement of important individuals (e.g. high-level government officials, foreign delegates, and international sports teams, etc.) is a common practice in developing countries. Congestion is divided into two types: recurring and non-recurring. Recurring congestion is expected to occur at the same time (peak hours), while congestion associated with unexpected or non-typical events is non-recurring congestion. Congestion is a pressing issue in all major cities worldwide, causing adverse effects on the economy, environment, and well-being of the community [1–3]. Developing countries have been affected by an increase in private vehicle ownership and poor management of resources, leading to a burden on existing infrastructure [4]. This trend is also observed in Pakistan, where 2 million new cars were registered in the last decade [5], and the rate of urbanization is the highest in all of South-Asian countries [6]. The increase in motorization and poor management has resulted in traffic congestion in major cities of Pakistan, worsening travel time, carbon footprints, and environmental pollution.

Congestion costs billions due to loss of productivity, fuel consumption, and environmental damage [7]. Various studies have attempted to quantify the impacts of both recurrent and non-recurrent congestion. The annual cost of congestion was estimated to be around USD 10 billion in a study conducted by the Department of Transport and Regional Service Australia [8]. In the United Kingdom, traffic congestion's total cost was approximately USD 30 billion in 2004, which was predicted to increase in the future [9]. A study in Antofagasta, Chile, found that the traffic congestion cost on a typical working day was approximately USD 1.02 million [10], while another study estimated the annual congestion cost of USD 3.868 billion for Dhaka city, Bangladesh [11]. Similarly, a study conducted in

Karachi, Pakistan, predicted a recurrent congestion cost of approximately 1 million PKR per day [12]. However, the excess emissions of air pollutants and their impact on public health require further characterization. Previous studies have focused on recurrent traffic congestion, and there is a lack of literature on non-recurrent congestion caused by planned special events (PSEs). PSEs are a major cause of significant disruptions in traffic flow over entire road networks, so this study aims to better understanding their impacts by analyzing economic and environmental factors to develop effective mitigation strategies.

VIP movements are a type of PSEs where certain intersection legs and link roads are blocked, allowing only protected one-way movement for important individuals. VIP movements do not generate demand themselves, unlike PSEs. Instead, once the blockage is removed, the resulting volume exceeds the network's capacity and leads to congestion. The implementation of these blockages is primarily for safety reasons, particularly in Pakistan, which has played a frontline role in the war against terror since the early 2000s. However, this practice has not been fruitful as it generates congestion, particularly during peak hours, over the entire network, making people more vulnerable and easy targets. Road users are left with two choices: remain in congested traffic or adopt alternative linked routes. This causes the entire road network to be congested for an extended period, which also affects necessary emergency services (e.g. ambulances, fire-fighters, and other resume response units), resulting in a waste of resources and time for various stakeholders. This study aims to shed light on the impact of such practices, resulting in economic costs related to travel time and carbon footprints, and to influence policymakers to draft policies that fulfill sustainability objectives, particularly in a country with war-torn economic conditions.

1.1 Study Area

Study area is situated in Twin cities of Islamabad and Rawalpindi in Pakistan. These cities together form third largest metropolitan in Pakistan with a population exceeding 4 million

[13]. It is vital to consider the traffic of Rawalpindi in connection to Islamabad because most of the daily commuters destined to Islamabad have trip origin based in Rawalpindi city. For this study a 23-km route between Chaklala Airport Rawalpindi and Red Zone Islamabad was selected. The selected route is shown in Figure *1-1*.

Figure 1-1. Route opted for VIP movements (Source: Google Maps)

Chaklala Airport is used for flight operations of all national and international dignitaries instead of Islamabad International Airport due to security reasons. VIP convoys take Airport road and Islamabad expressway respectively to reach Fiazabad interchange from airport, from there these convoys take Muree road to reach Constitution Avenue that leads them to red zone. As a result of this many main arterials of Rawalpindi and Islamabad including Airport Road, Islamabad expressway and Srinagar highway are blocked. Five locations selected for micro simulation are mentioned below.

- Blockade 1: **B1** (33.603067, 73.096494): For traffic coming from Rawalpindi via airport road near Chaklala Airport
- Blockade 2: **B2** (33.600673, 73.134817): For traffic coming from Rawat via Islamabad Expressway near Kural
- Blockade 3: **B3** (33.668110, 73.084614): For traffic leaving Islamabad via Islamabad Expressway near Faizabad
- Blockade 1: **B4** (33.689188, 73.114002): For traffic entering Muree road via Park Road near Rawal Dam
- Blockade 1: **B5** (33.714353, 73.102440): For traffic on both side of Sirinagar Highway near Serena Hotel

CHAPTER 2: LITERATURE REVIEW

The proposed research is a cross disciplinary study of users willingness to pay, modelling of urban traffic and quantification of traffic congestion. This chapter will introduce the development of literature in above mentioned three areas in various countries across the globe. The details of the data collected, surveys conducted, Softwares used, the methodology used, analysis done along with summary of the results of past literature are also discussed.

2.1 Measurement of Willingness to Pay

This section provides an overview of various choice modeling studies related to data collection and value of time (VOT) estimations. Studies conducted in Europe, e.g. [14] in Norway, [15]in Sweden, [16] in the United Kingdom, and [17, 18] in Switzerland, have looked at VOT modeling. In a study conducted by [19], a meta-analysis was performed on 105 travel demand studies, utilizing revealed preference and/or stated preference methods, to examine the value of time (VOT).[20] Estimated VOTs for Greek drivers using revealed preferences and analyzed using a multinomial logit model. [21] Collected stated preference data via telephone survey in Greece and suggested incorporating socioeconomic data into the model formulation for further research. [22] Developed models for predicting travel decisions and transportation demand with mixed logit models using reveled-preference and stated-preference data to analyze different traffic management strategies.

Kawamura et. al Estimated VOT for commercial motor carriers in California using stated-preference data and a modified logit model with log-normally distributed coefficients [23]. In Finland, [24] conducted two separate studies to estimate VOTs for road and rail transport specific to freight. They used stated-preference data and logic model estimating coefficient that presented hypothetical choice situations.[25] Also performed meta-analysis of

VOT for freight in their study. [26] Estimated VOT, service headway, and comfort levels for rural bus travelers in India using a stated preference (SP) survey by developing a multinomial logit model. The SP survey included the trip and socioeconomic characteristics of respondents.

Various researchers have employed stated-choice approaches to measure user willingness to pay (WTP) [27–29]. [30] Used stated choice experiment to develop mixed logit models and estimate WTP for different road types. [31] Used a stated choice survey to estimate willingness to pay for reducing traffic risk and value of time. [32] Estimated the VOT of tourists visiting Teide National Park in the Canary Islands, Spain, using discrete choice modeling. Lastly, [33] estimated the VOT for a congested highway in Karachi, Pakistan, using multinomial regression models on SP data.

To sum up, most of the studies that estimated VOT utilize discrete choice models with a preference for the logit models. Recently, more advanced models such as mixed logit have been used. Questionnaire-based surveys are the primary data collection method used by most of the scholarly articles discussed in this section. The collected data can be of SP or revealed preference (RP) nature. To estimate demand equations use of RP data is an advantage as the RP data is consistent with economic theory and market behavior. SP data, on the other hand, come from hypothetical experiments and offer advantages such as the ability to collect data about hypothetical or unavailable options or attributes [34]. Quality issues that might be present in RP data can be limited by using SP Survey data. Therefore, most studies utilize SP data for VOT modeling.

2.2 Modeling of Urban Traffic Congestion

When traffic demands of a network exceed its available capacity such a state is called Traffic congestion. This congestion result in travel time delays and formation of long queues on road until demands decrease. Traffic simulation models are used to model and study urban traffic congestion all around the world. Some studies which are indirectly related to this thesis topic that used microscopic simulation for the analysis and evaluation of different urban traffic scenarios are discussed below.

Jana Fabianova et. al used VISSIM software to test and design an intersection model to minimize congestion [35]. For this purpose traffic survey was conducted on two working days and turning movements for 15 minute interval were recorded along with geometry of the intersection. Traffic was modelled and simulated on selected intersection three time, once for existing state and twice with some modification to improve intersection performance. Length of queues at intersection was selected as the performance criterion for intersection. Simulation after first adjustment resulted in reduction of queue length by 75% whilst second model further improved passage of right turn vehicles. The purpose of this study was to design and evaluate a traffic-light-controlled intersection using VISSIM program.

Roger V. Lindgren et. al used computerized microscopic traffic simulation programs Paramics and VISSIM to analyze a diamond interchange in Portland, Oregon metropolitan area at intersection of Interstate 5 and Wilsonville Road [36]. A rail crossing and four closely located signalized intersection were also included in study area. The study discusses steps required to model vehicle maneuvering and driver behavior in each simulation model. The study also draws an empirical comparison of travel times and delays predicted by simulation models with those predicted by the 2000 Highway Capacity Manual. This paper also discusses modeling of geometric as one of strengths of simulation models. These models allow designers to analyze non existing situations like addition of new lane or turn bay etc. During the study it was found that after coding an validation of initial on-field network it was very simple to study the impact of geometric changes using both Paramics and VISSIM.

Gill M S Mosseri et. al studied a multi-modal urban corridor with Complex Geometry and traffic control on VISSIM [37]. This was a case study of urban arterial called Ocean

Parkway in Brooklyn, New York. For this purpose an elaborate data collection program was conducted on Ocean Parkway. Data included travel time surveys, automatic traffic recorder counts, turning movements counts (both vehicular and pedestrian/bicycles). Limited origin-destination counts were also conducted. Due to complexity of Ocean Parkway corridor, a combination of Excel, Synchro / SimTraffic and VISSIM was used analyze the corridor. Capacity analysis and signal optimization was conducted using Synchro / SimTraffic while detailed micro simulation of the network was done on VISSIM.

Gabriel Gomes et. al constructed and calibrated Micro-simulation Model of a congested freeway in Pasadena, California using VISSIM [38]. In this study a 15 mile stretch of freeway was used as study area which included 20 metered on-ramps, a high-occupancy vehicle (HOV) lane and a heavy freeway connector. In order to model this on VISSIM two separate sources were used to collect field data. On the on-ramps and main line loop detectors were used while 15 minute Manual counts were conducted on the on-ramps and off-ramp in the test site.

Enrique González modeled a 13 km corridor in Mayagüez, Puerto Rico. In his study VISSIM model was calibrated for Puerto Rican Traffic Behavior [39]. For this purpose data was collected on selected corridor and a comparison was drawn between simulated results and on field conditions. The research showed a 95% confidence level that VIISIM represented traffic behavior with no significant difference from on field traffic.

Chen et. al used a combination of Driving Simulator and VISSIM to Asses Influence of Adverse Weather on Traffic Flow Characteristics [40]. Studies based on field collected data have a limitation that it is difficult to analyze influence of weather conditions on traffic flow characteristics as they are both non-repeatable and non-controllable. This study overcome the limitation by conducting weather-related driving experiment on driving simulator to collect driving behavior data and used it in VISSIM to simulate and evaluate the changes in traffic flow characteristics caused by it. This study shows how micro-simulation can be used to analyze impact of uncontrollable and non-repeatable special events on traffic conditions.

The studies discussed in this section demonstrate the usefulness of micro-simulation tools for analyzing complex traffic scenarios, including intersection designs, multi-modal urban corridors, and congested freeways. Simulation models allow designers to analyze non-existing situations such as the addition of a new lane or turn bay and to study the impact of geometric changes. They can also be used to assess special events such as adverse weather, road accidents, and planned special events (PSEs) on traffic flow characteristics.

2.3 Quantification of Urban Congestion

Urban traffic congestion cost billions of dollars globally due to increase in travel time, emissions and extra fuel consumption. Economic impact of traffic congestion include opportunity cost lost due to lose of travel time and cost of additional fuel used. Summary of some studies conducted to quantify economic impact of urban traffic congestion is given below;

Goodwin [9] published used data of traffic volume, congestion delays, free flow speed and value of time to estimate economic cost of traffic congestion in his working paper. He estimated annual cost of congestion in UK to be around USD 30 Billion in year 2004 and predicted that it might go up to USD 50 Billion by year 2010. This study purposed a plan of congestion charging in order to reduce urban traffic congestion. Goodwin argued that it will never be economically feasible to increase road infrastructure capacity with the current rate of motorization so a combination of congestion charging and supportive measures like public transport, cycling lane etc. can decrease congestion cost by 40%-50%.

Australia government commissioned Bureau of Transport and Regional Economics (BTRE) to examine the main and emerging causes of urban traffic growth and its impact on urban traffic congestion [8]. The study uses consistent aggregate methodology to estimate current cost of congestion and projects its variation in the future. This approach is advantageous as it allows estimation and projection of congestion cost in less data intensive manner than detailed network models but for higher accuracy of estimates detailed network modeling is necessary. This study estimates the combined annual cost of traffic congestion to be round USD 10 billion for all Australian cities. This estimate include private and business time cost as well as operating cost.

Nicolás et. al used a micro-simulation exercise to Compute the cost of traffic congestion in Antofagasta, Chile [10]. Opportunity cost of people stuck in traffic due to congestion was aggregated to compute cost of congestion. Wage rate method was used to estimate the opportunity cost of people stuck in traffic jams. For the purpose of micro-simulation city was divided into fourteen districts and a simplified road network was proposed. Available micro data was used to calibrate parameters of the simulation. During a working day, Congestion cost of Antofagasta, Chile was estimated to be around US$1.02 million.

Attempts to quantify urban traffic congestion have been made in almost all South-Asian countries. Summary of few such studies are as follows;

Bivina et. al estimated cost of traffic congestion in capital of Kerala, India to be around 83.85 Crores INR per annum [41]. This study utilized data of Willingness to pay, classified traffic counts and passenger occupancy to estimate travel time cost, fuel lost cost and environmental cost. These costs are aggregated to calculate total cost of traffic congestion. Data was collected on six intersection of corridor for three days. This study uses graphical/slope method to calculate value of time and for delay calculation floating car method was used.

S.Karthik et. al developed a congestion model for Kerala, India. The study indicates that cost of congestion in Kerala was equal to almost 25% of total expenditure on road infrastructure in 2021 budget [42]. 18.9 km road stretch divided in 12 segments was selected as study area. Traffic counts were taken on weekdays at three different times; 8:00 AM- 10:00 AM, 12:00 PM – 2:00 PM and 4:00PM-6:00PM. VOT calculations were based on an online questionnaire survey counted from Kerala residents while floating car method was used to estimate delay.

Tanzila et. al studied traffic congestion in Dhaka studied and estimated its cost by calculating Travel time cost (TTC), environmental cost and vehicle operating cost (VOC) due of citizen stuck in traffic jams [11]. This study also calculated externality cost due to travel time and delay avoidable social costs of congestion. Value of time (VOT) approach was used to calculate travel time cost. This study uses willingness to pay survey conducted in 2010 and makes allowance for three years by using a 1.5 time greater VOT. The total cost of traffic congestion in Dhaka was estimated to be around USD 3868 million in this study which include TTC of 1499 million per annum.

Jayasooriya et. al measured economic cost of congestion in Galle, Sirilanka [43]. For this purpose socioeconomic survey conducted on Galle corridor to calculate Value of time. Socioeconomic survey included question related to working hours, willingness to pay, fuel consumption, travel distance, travel time etc. Vehicle counts and bus data was collected from BRT surveys. The main purpose of this research was to establish an analytical method for VOT and VOC estimation and to examine current economic efficiency level of Galle corridor. This research has a limitation that it uses vehicular counts of year 2014 while socio-economic survey was conducted in year 2016. Thus to fill the two year gap traffic was multiplied by an assumed growth rate of 1.5%.

Mir et. al in studied a 25 km road stretch divided into 9 observation points to quantify traffic congestion in Karachi, Pakistan [12]. Socio-economic data was collected using questionnaire survey while Traffic counts were calculated using camera mounted vehicle.

Based on the collected data and observed results, the total direct traffic congestion cost was around 3million PKR per day (30,440 USD per day) for the road stretch under study. On per year basis, this figure will be approximately 11 million USD. Overall, these studies demonstrate that urban traffic congestion incurs significant monetary and environmental costs to society.

CHAPTER 3: METHODOLOGY

The following framework has been adopted and shown in Figure *3-1*.

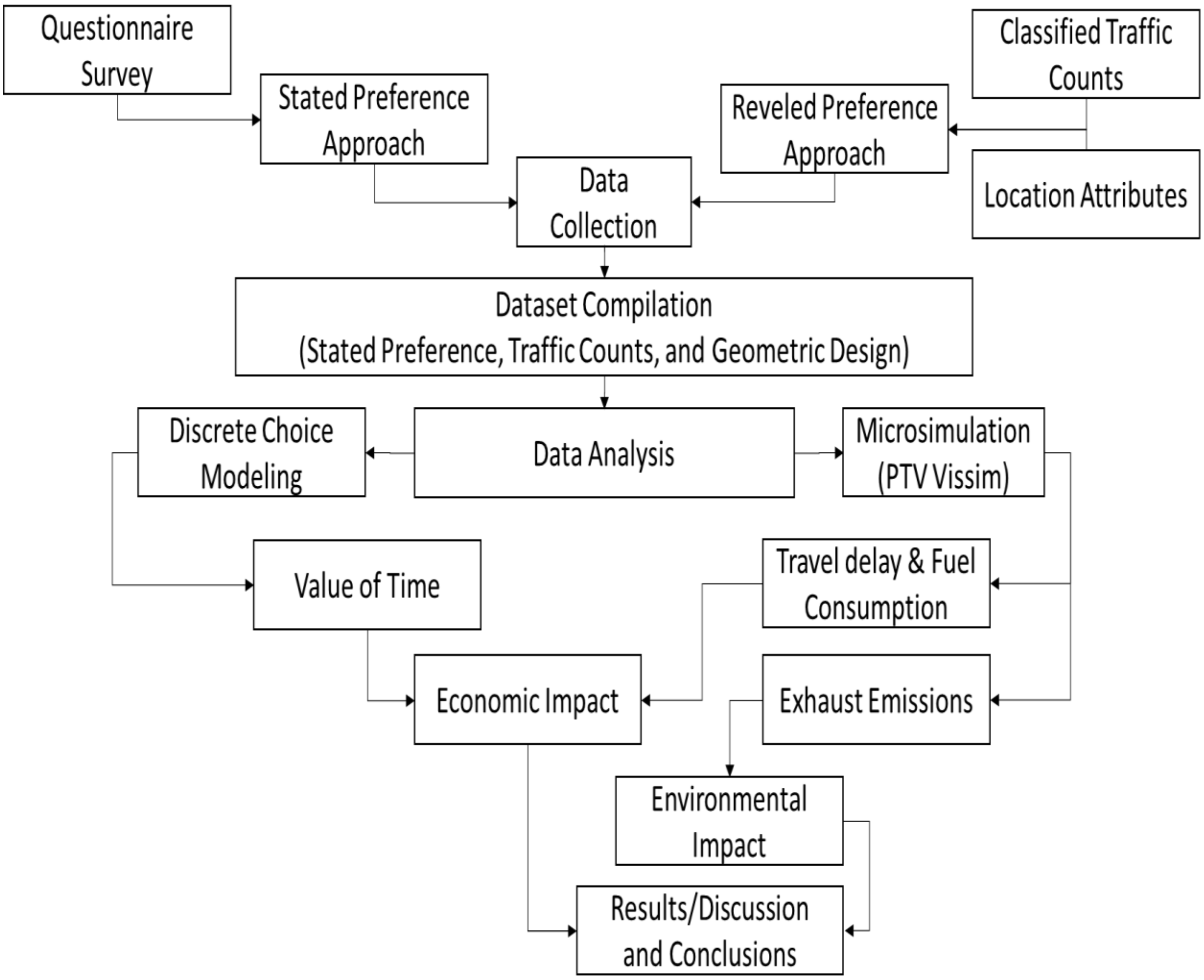


Figure 3-1. Methodology framework

3.1 Questionnaire Design

A SP questionnaire was structured to take advantage of its positive aspects like flexible experimental and inclusion of non-existent alternative as mentioned in literature review. Guideline provided by Wattam et al. [44] to create such survey were also utilized. The questionnaire consisted of three sections; demographic information, daily trip information and stated preference questions.

In first section socio-economic and demographic information of each respondent was recorded. In second section the respondents were asked to answer a few related questions related to trip they take most frequently like trip purpose, frequency the trip is done per week, average trip duration etc. In last section each individual was presented with four distinguish routes wherein they were asked about the preferred mode choice. Each mode choice was equipped with various combination of parameters travel cost, journey travel time, and waiting time in case of using public transport.

3.2 Data Collection

This step involved collection of two different data sets; mode choice data using SP survey and traffic volume and inventory data using traffic count survey.

Questionnaire designed in first step was used for SP survey. SP Survey was conducted primarily based on convenience sampling and partially on snowball sampling. Convenience sampling is a non-probability sampling technique in which easily accessible consumers were chosen [45] to determine different socio-economic factors affecting mode choice behavior and collect choice data. Snowball sampling is another type of non-probability sampling technique in which the sample subjects help the researcher in recruiting more sample subjects for the study [46]. This technique is beneficial for surveying hard to reach individuals [47]. Both method; traditional (pen and paper) and digital platforms (Google forms) were utilized for this survey.

Second data set included information related to Existing geometry (Number of lanes, lane width etc.), inventory details (speed limit, signs, signal timing etc) and Traffic volumes for all five location discussed in study area. The dataset mainly belong to the two rush hours of morning and evening noted as 7:00am to 10:00 am and 4:00pm to 8:00pm respectively. Volume data comprises of different travel modes such as: Cars, Motorcycles, Public Transport and Trucks.

3.3 Data Analysis

3.3.1 Discrete Choice Modelling

The selection of the unordered choice model, also known as the multinomial logit model, was based on the literature discussed in **Section** Error! Reference source not found.. This particular model is grounded in the theory of utility maximization, where each decision maker assigns a value to each option in the available choices and selects the one with the highest value. Since the exact value cannot be directly observed, a probabilistic approach is employed, giving rise to the random utility theory [48].

To formulate and estimate a simple multinomial logit model, we adapt **Equation 1-4** from [48]. In this model, each decision maker (n) associates a utility value $U_{n,i}$ with alternative i. This utility value is composed of two components: a deterministic or observable utility$V_{n,i}$, and a random or error component $\varepsilon_{n,i}$. The deterministic utility is determined by the observed variables x_{ni} for alternative i. The probability of decision maker n choosing alternative i can be calculated using **Equation 2**.

$$U_{n,i} = V_{n,i} + \varepsilon_{n,i} \quad where \ \ V_{n,i} = f(\beta, x_{ni}) \qquad \text{Eq. 1}$$

$$P_{ni} = Prob\ (V_{n,i} + \varepsilon_{n,i} \ \geq \ V_{n,j} + \varepsilon_{n,j}\ \forall\ j\ \ ) \qquad \text{Eq. 2}$$

To obtain a closed-form solution for the multinomial logit model (**Equation 3**), the error terms associated with all alternatives are assumed to be independently and identically distributed. In this case, a type 1 extreme value distribution, commonly known as a Gumbel distribution, is utilized. This distribution allows for a mathematical expression that enables the modeling and analysis of the multinomial logit model. The model parameters, represented by $\beta\ in\ f(\beta, x_{ni})$, are estimated by maximizing the log likelihood (LL) function **(Equation 4).**Research conducted by [49] has shown that the log-likelihood function exhibits global concavity, implying that a single and unique solution exists.

$$P_{ni} = \frac{e^{Vni}}{\sum_{j=1}^{J} e^{Vn,j}} \qquad \text{Eq. 3}$$

$$LL(\beta) = \sum_{n=1}^{N} \sum_{i} y_{ni} ln\,(P_{ni}) \qquad \text{Eq. 4}$$

where:

y_{ni} *is the observed choice.*

The general formulation of the utility function in the present study's case is given by **Equation 5**:

$$U = \beta_0 + \beta_{time}.TT + \beta_{cost}TC + \cdots \qquad \text{Eq. 5}$$

where:

β_0 = Intercept

TC = Travel cost

TT = Travel time

β_{cost}= Coefficient of travel cost (utility /Rs.)

β_{time}= Coefficient of travel time (utility /min)

"…." Corresponds to other explanatory variables of the model

Afterward, using the derived coefficient of travel cost and travel time, the Value of time (VOT) is calculated in PKR/min was estimated in the following way:

$$VOT = \frac{\beta_{time}}{\beta_{cost}} \quad \text{Eq. 6}$$

3.3.2 Micro Simulation

Traffic volume and geometric information data acquired in traffic count survey was used to model existing situation of all five locations in VISSIM. In order to create model in VISSIM satellite image of all five locations were loaded as background image and scaled according to on field situations. Next step was to draw links and connecters as per geometric design data collected from field survey. Default setting for dimensions of vehicle were used during simulation. Traffic volume was assigned at the beginning of each road segment and traffic composition was input as per data collected in vehicle count survey. Poisson distribution was used to load the assigned traffic volume in random manner [50].

First existing conditions were modeled and simulated for each location on VISSIM i.e., signalized intersections were analyzed with existing signal timings while free segments were simulated with all green. Psychophysical driver behavior model developed by R. Wiedermann was used as basis of car following and lane changing logic. Node evaluation was used to estimate exhaust emissions and fuel consumption. Exhaust emissions and Fuel consumption are calculated by utilizing Oak Ridge National Laboratory's data on emissions [51] and TRANSYT 7-F program's formulas for fuel consumption [52] respectively in node evaluations.

Secondly to create the scenario of blockade due to VIP movement, a red-green signal was introduced on all lanes of roads at all five location in VISSIM model. Red time was incremented by two minutes in each simulation cycle to check the impact of different stoppage time durations on different measures of effectiveness.

3.3.3 Economic Impact Analysis

Delay per vehicle, fuel consumption, and value of time was used to estimate the economic impact of congestion caused by VIP movements. The travel time delay cost and fuel consumption cost were calculated for each scenario, and the total cost of road blockage was determined by adding these two costs (using discrete modeling) together.

$$TDC = TTDC + FCC \qquad \text{Eq. 7}$$

Equation 8 was used to measure the delay cost of this study. The approach used is to impose the VOT on the calculated delay, which is a widely accepted method [41].

$$TTDC = \sum (TTD \times VOT \times N) \qquad \text{Eq. 8}$$

where:

TTDC Travel time delay cost

TTD Simulated Travel time delay

VOT Value of travel time

N Number of vehicle

The vehicle operating cost or fuel loss cost is determined by multiplying the fuel cost with the amount of additional fuel consumed by a vehicle while stuck in congestion. To calculate the extra fuel consumed due to road blockages, fuel consumption analysis in VISSIM was used in this study. The economic loss due to fuel was then calculated by multiplying fuel loss with the prevailing cost of fuel.

$$FCC = \sum (FC \times f_c) \qquad \text{Eq. 9}$$

where:

FCC	Fuel Consumption cost
FC	Fuel consumption
f_c	Fuel cost

3.3.4 Environmental Impact Analysis

The environmental impact of road blockages for VIP movements was assessed by comparing the amount (quantity) of pollutants emitted during different durations (time) of blockades. In this study area, all blockades were analyzed using VISSIM to estimate the emissions of pollutants (e.g. CO, NOx, and VOC (Volatile organic compounds)).

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Sample Characteristics

A group of 445 individuals participated in the survey, but only 401 unique entities were selected for data analysis after scrutinizing responses for missing information and incomplete surveys.

4.1.1 Gender

Figure *4-1* shows gender distribution of the selected respondents. Females were reluctant to answer survey therefore majority of the participants (85%) were male.

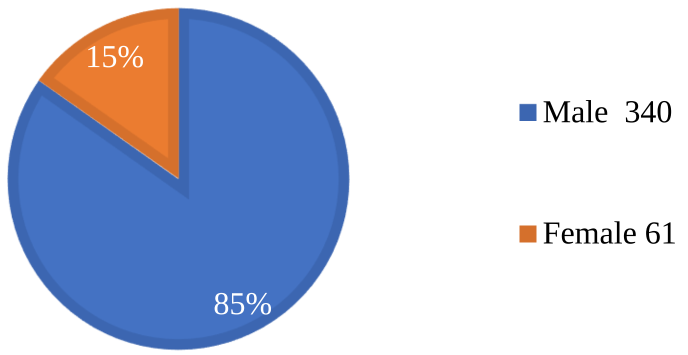


Figure 4-1. Gender

4.1.2 Age

Young participants were more cooperative therefore most of respondents were between the ages of 18-30. Figure *4-2* shows the age distribution of respondents.

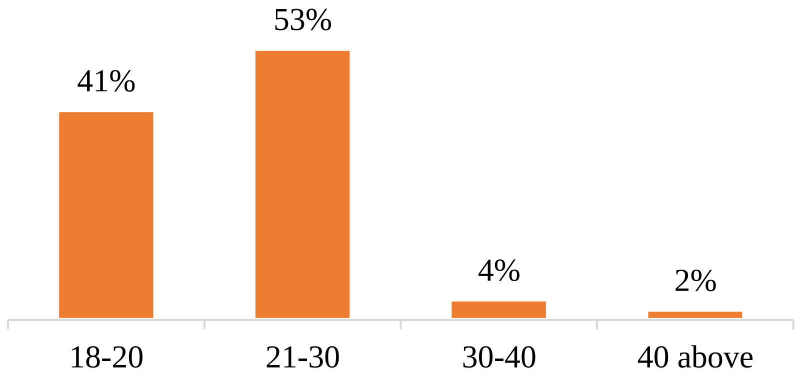


Figure 4-2. Age

4.1.3 Income

A vast majority (78%) of respondents reported their income below PKR 40 thousand. Only 12% people reported their income above PKR 60 thousand. Based on this high income category was created in discrete choice modelling. Figure *4-3* shows income distribution of participants.

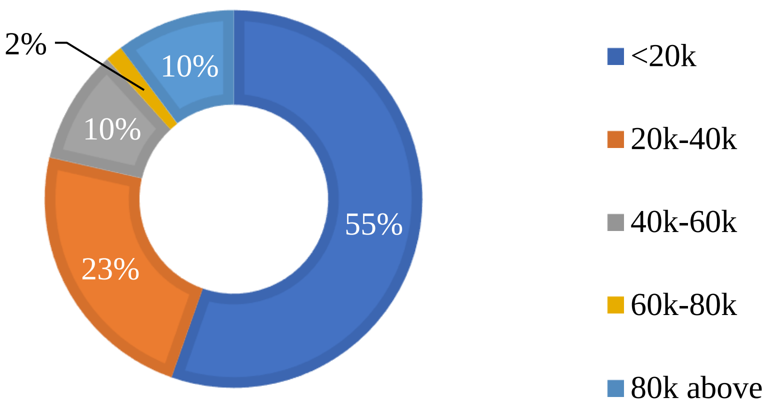


Figure 4-3. Income

4.1.4 Emolument status

Nearly half (46%) of participants reported themselves employed while rest (56%) reported themselves as unemployed.

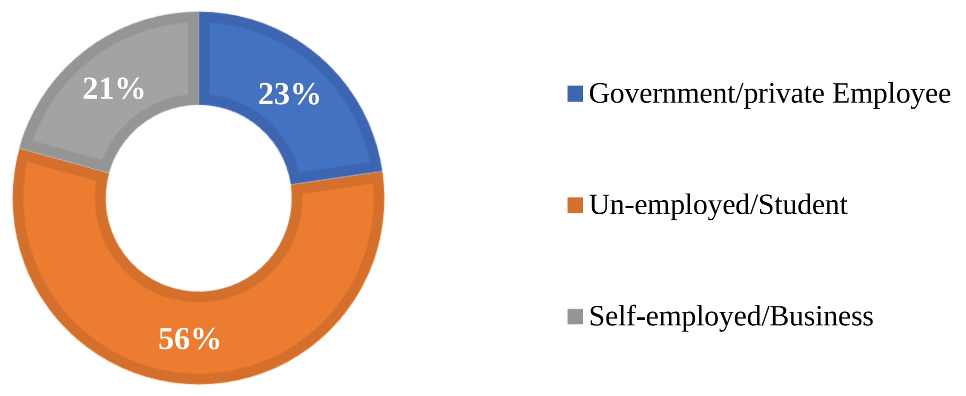


Figure 4-4. Employment status

4.1.5 City of residence

Majority (62%) of respondents were from Islamabad. Figure *4-5* show the geographic distribution of respondents.

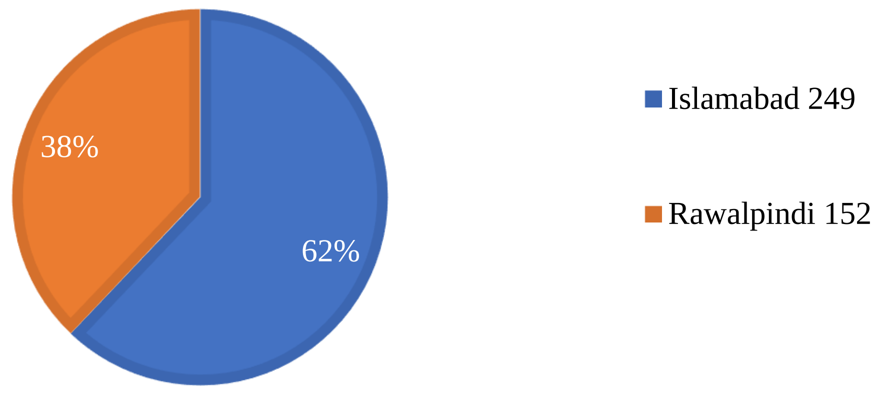


Figure 4-5. City of residence

4.1.6 Purpose of travel

Education was reported as prime motive of daily travel by 59% participants. **Figure 4-6** show the purpose of daily travel of respondents.

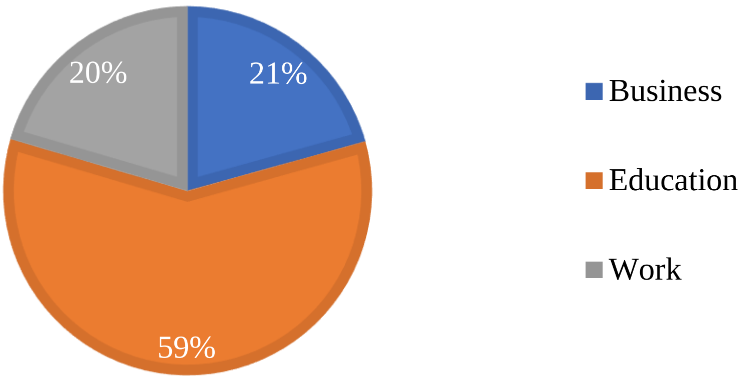


Figure 4-6. Purpose of daily travel

4.1.7 Mode of travel

Figure *4-7* show the mode opted by respondents for daily travel. Car was most preferred while public transport was least preferred mode of travel.

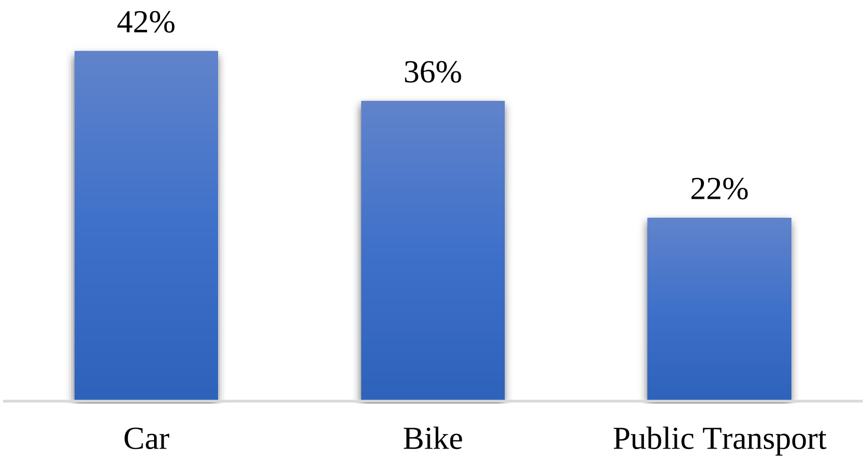


Figure 4-7. Mode of daily travel

4.1.8 Vehicle Ownership

Figure *4-8* shows the vehicle ownership status of respondents. Only 21 % people reported that they did not own a vehicle.

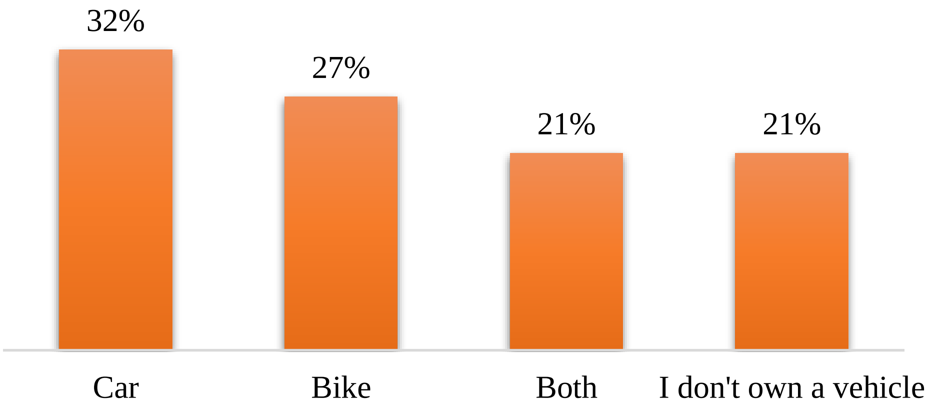


Figure 4-8. Vehicle ownership

4.2 Model Estimation

The model was implemented and estimated with the Apollo choice modeling library in the R language [53]. Initially, only the primary variables of travel cost and travel time were included in the model specification. Relevant explanatory variables were incrementally added to the model, based on summary goodness of fit measures, such as log-likelihood and AIC and significance of the estimated parameter coefficients. The steps and probability values of corresponding likelihood ratio tests are listed in Table *4-1*. Initially, coefficients of travel cost and travel time were generic for all choices. Then, the beta (β) coefficients of travel time were varied for each mode, but the log-likelihood test was found to be statistically insignificant. Therefore, the first model was adopted over the second. Gender was included in the utility function first generically and then separately for each mode, where the β coefficients were found to be statistically significant in both cases. However, a better log-likelihood was achieved in the second case.

Table 4-1. MNL Model formulation with likelihood ratio tests

S. No (i)	Model	Log Likelihood	LL Ratio Test value	Degree of Freedom Added	Likelihood p value
1	Base model (general β for travel time and travel cost)	-1554.12	-	-	-
2	β time distributed for each choice	-1554.03	0.18	2	0.91 **
3	General β for gender introduced	-1529.39	49.46	1	2.03E-12*
4	β gender distributed for each choice	-1456.5	145.78	1	1.45E-33*
5	β for high income category introduced	-1452.53	7.94	1	0.004835*
6	β for young age category introduced	-1452.53	0	1	1**

* Indicate the results that are statistically significant at a 99% confidence interval, leading to the rejection of the null hypothesis. Therefore, model $i + 1$ is preferred over model i.
** Indicates the test results that are not statistically significant at 90% confidence interval.

Age as a contributing variable was found to be statistically insignificant in the utility function for all modes. Categorizing age into different groups did not result in significant β coefficients or log-likelihood improvement, therefore age was not included in the final model. In contrast, a high-income category was introduced for individuals with an income of 60 thousand or more, and the maximum log-likelihood was achieved by introducing a high-income coefficient for cars.

The final model results, reported in Table *4-2*, show that all coefficients are significant at the 99% confidence interval except for income, which is statistically significant at the 90%

confidence interval as shown in the t-value of income. The negative coefficients for travel time and travel cost, along with the meaningful VOT, indicate a good fit for the model. Interestingly, the coefficient of gender (female) is negative for bikes, indicating that women have a strong preference for cars over bikes, while the coefficient of gender (female) is positive for vans, suggesting that women prefer vans over cars.

The positive coefficient for the high-income category indicates that as income increases, the probability of choosing a car over other modes of transportation also increases.

Table 4-2. Model estimations

	Estimate	**Std.err.**	**t-ratio(0)**	**Rob.std.err.**	**Rob.t-ratio(0)**
asc_car	0	NA	NA	NA	NA
asc_bike	-0.31797	0.2105398	-1.510276363	0.1593545	-1.99*
asc_van	-1.87931	0.22901849	-8.205915717	0.2102371	-8.93*
b_tt	-0.0188	0.01105408	-1.700901258	0.0066334	-2.83*
b_cost	-0.00285	0.00120364	-2.365787493	0.0007567	-3.76*
b_female_car	0	NA	NA	NA	NA
b_female_bike	-2.55827	0.2846348	-8.987896204	0.358116	-7.14*
b_female_van	0.630919	0.17841238	3.536294459	0.3020474	2.08*
b_high_income	0.459343	0.16384099	2.803593086	0.2681092	1.71**
LL(start)	: -1762.17				
LL(final)	: -1452.53				
Adj.Rho-squared	: 0.0628				
AIC	: 2919.06				

*Significant at 99% confidence interval & **Significant at 95% confidence interval

Table *4-3* displays the calculated VOT estimated using **Equation 6**. The value of time was determined to be *6.60 PKR/min (396 PKR/h),* which is equivalent to *1.77 USD/h***.** This value falls within the range of the previous value of time studies [54] and [33] carried out in Pakistan, whose VOT estimates were *0.41 USD/h* and *3.67 USD/h* respectively. Since both of the previous studies were carried out in Karachi, the slight difference in the results of the current study may be due to demographic variation between the locations of the three studies.

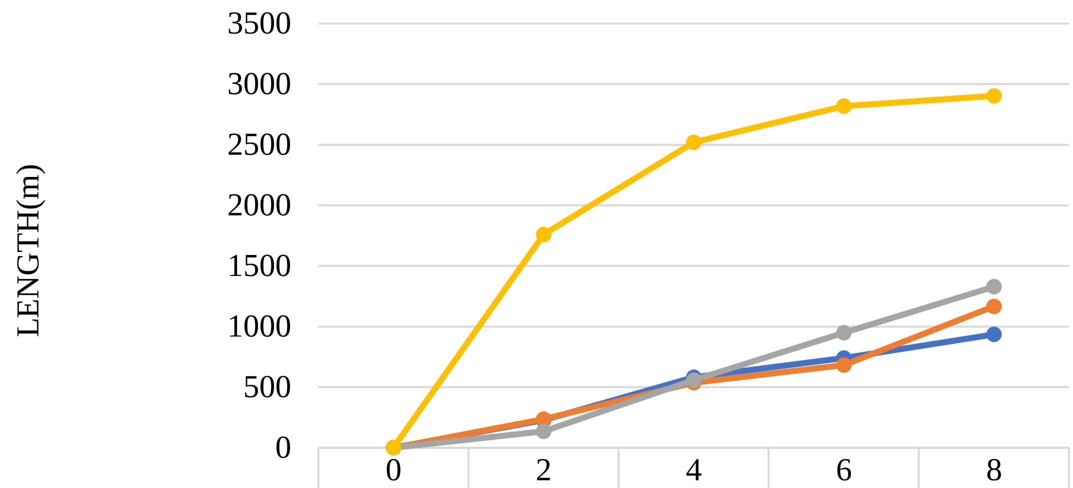
Table 4-3. Value of time (VOT)

Expression	**Value**	**Robust s.e.**	**Rob t-ratio (0)**
VTT_min	6.6029	2.1772	3.03
VTT_hour	396.174	130.6349	3.03

4.3 Simulation Results

4.3.1 Freeway Segments

Figure *4-9* shows the queue increase in maximum queue length at freeway sections for each blockade time. Initially the queue length was zero at all freeway locations. The increase in queue length was gradually for blockade 1 to 3. These three blockades were located at multilane divided highways therefore queue grew gradually. Blockade 4 was located at two lane divided urban arterial named Park Road therefore the growth in queue was exponential at this point.



	0	2	4	6	8
B1: Airport Road	0	227	581.06	740.06	935.07
B2: Expressway Kural	0	236.27	536.48	683.4	1166.62
B3: Expressway Faizabad	0	135.45	559.33	950.19	1328.24
B4: Park Road	0	1760.76	2519.71	2819.71	2903.99

Figure 4-9. Queue length (freeway segments)

Figure *4-10* shows the delay per vehicle for each blockade interval at freeway segment. Initially the delay was zero at each location. The delay per vehicle grey sharply as blockade time went beyond two minutes.

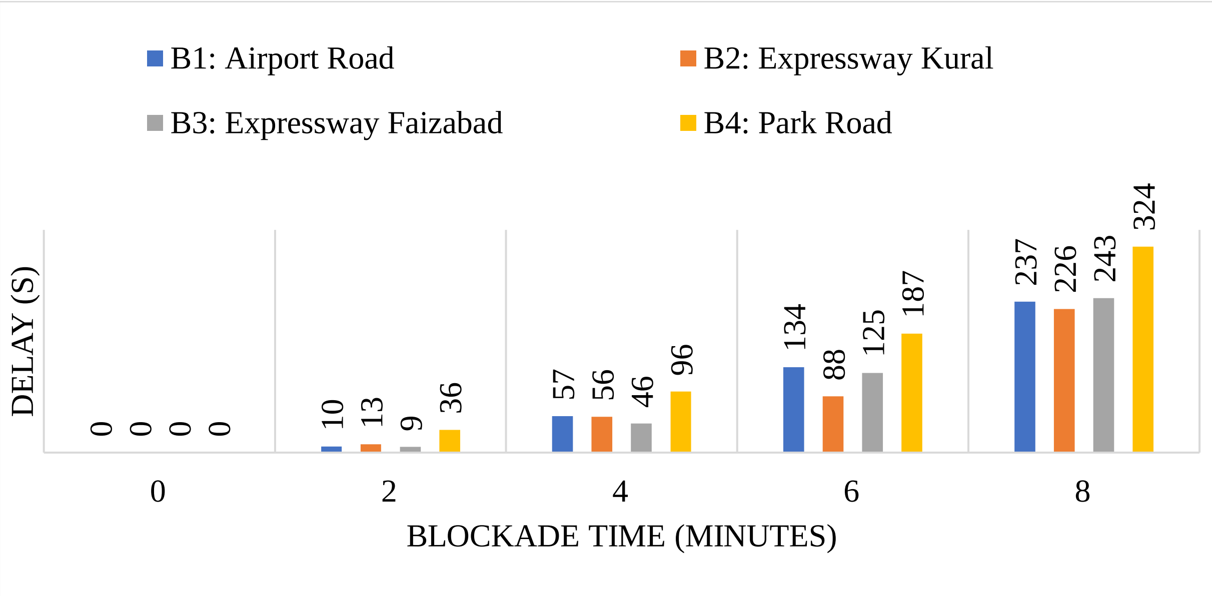


Figure 4-10. Delay (freeway segments)

4.3.2 Signalized Intersection

Figure 4-11 & Figure *4-12* shows the impact of different blockade intervals on the delay and maximum queue length at an existing signalized intersection.

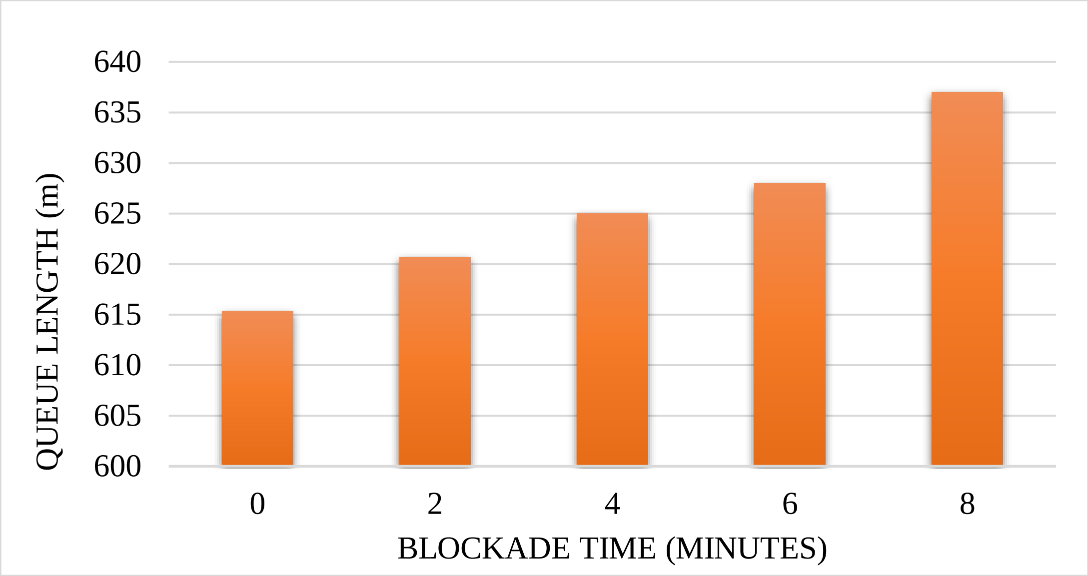


Figure 4-11. Queue length (signalized intersection)

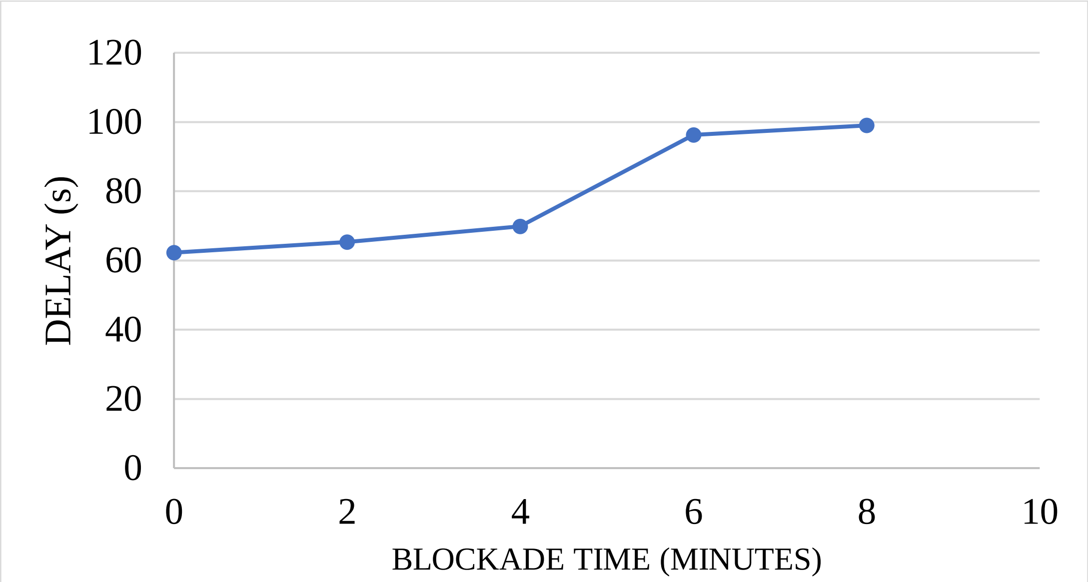


Figure 4-12. Delay (signalized intersection)

4.4 Economic Impact Analysis

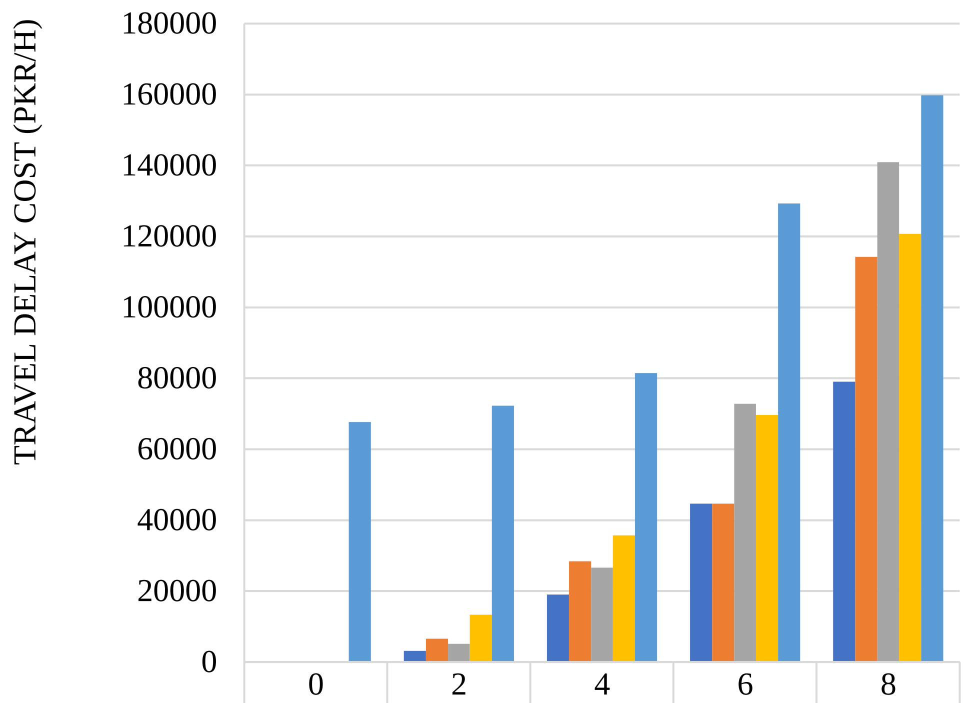
The economic impact of traffic congestion caused by VIP movements was calculated by using VOT estimated in the previous section, along with the travel delay and additional fuel consumption estimated via microsimulation. The microsimulation analysis was divided into variant-0, where the current state was modeled, and variant 1-4, where 2 minutes of blockade time were added for each variation, and the blockade time was incremented gradually from 2 to 8 minutes. This was done to model the impact of blockade time on travel time delay and fuel consumption of vehicles stuck in congestion.

4.4.1 Existing Delay Cost (Variant-0)

The travel time delay cost (TTDC) was estimated using **Equation 8**, and the results of each variation of a blockade at all locations are shown in Figure *4-13*. The existing delay cost was estimated to be 67,650 PKR per hour at B5-Serena while the delay cost was zero at all other locations due to them being freeway segments

4.4.2 Scenario Runs (Variant 0-4)

The blockade time is indicated for each variation along the x-axis of Figure *4-13*. The results indicate a small increase in travel delay cost as the stoppage time increase from zero to 2 minute. However, the travel delay cost almost quadruples as the blockade time is increased from 2 minutes to 4 minutes. The only exception to this sudden increment is the B5 intersection, where the increase, though significant, is a little less drastic.



	0	2	4	6	8
B1: Airport Road	0	3188	19058	44686	79020
B2: Expressway Kural	0	6597	28412	44686	114205
B3: Expressway Faizabad	0	5120	26627	72845	140935
B4: Park Road	0	13384	35755	69645	120709
B5: Serena	67650	72245	81425	129289	159750

Figure 4-13. Travel time delay cost all locations PKR/h

4.4.3 Fuel Consumption Cost

Fuel consumption analysis was conducted using VISSIM to estimate the impact of different blockade timings on fuel consumption. The fuel loss cost for different blockade intervals was estimated by multiplying fuel consumed with the average fuel cost of the last six months. Table *4-4* shows the variation in fuel consumption cost with respect to different blockade-time estimated using **Equation 9**.

Table 4-4. Fuel consumption cost for different scenario runs

Blockade Time (min)	Total Fuel Consumed (L/h)	FUEL COST (PKR/L)	FUEL CONSUMPTION COST (PKR/h)
0	487	264	128569
2	616	264	162709
4	991	264	261697
6	1238	264	326775
8	1552	264	409823

4.4.4 Total Cost of Delay

Table *4-5* illustrates the variation in total delay cost for different blockade interval estimates using **Equation 7**. The total delay cost was calculated by adding the estimated travel delay cost and fuel loss cost from the previous two sections.

Table 4-5. Total delay cost for each scenario run

Blockade time	Total TTDC (Rs/h)	FUEL CONSUMPTION COST (Rs/h)	Total Delay Cost
0	67650.087	128569.15	196219
2	100534.3	162708.88	263243
4	191277.37	261697.32	452975
6	361150.11	326774.88	687925
8	614618.64	409822.72	1024441

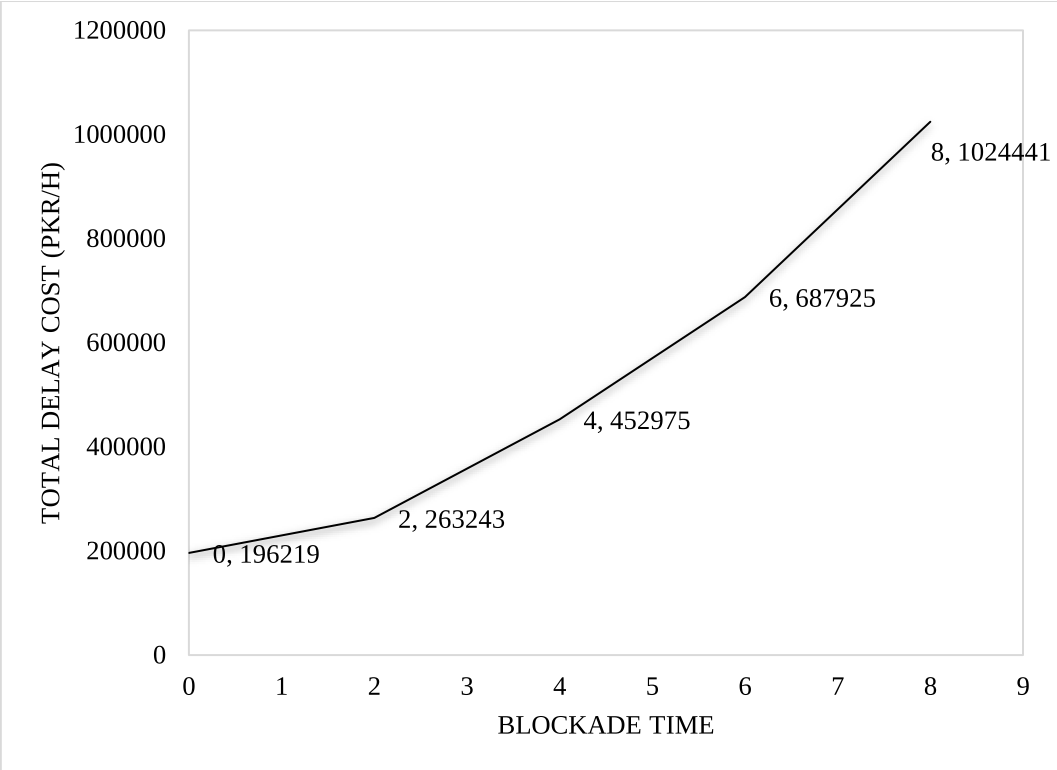


Figure 4-14. Increment in total delay cost with respect to blockade time

Figure 4-14 indicates that the total delay cost increases gradually with an increase in the blockage time from zero to two minutes. However, beyond two minutes, the rate of increase in delay cost becomes steeper. During the initial two minutes, the rate of increase is 33,512 Rs/h for every minute of blockade time. This rate doubles to 94,866 Rs/h when the blockade time goes beyond two minutes and approaches four minutes.

4.5 Environmental Impact Analysis

Microsimulation analysis of the five locations provided data on CO, NOx, and VOC generated by vehicles in the network. Similar to the travel delay and fuel consumption analysis, this analysis was divided into a variant-0 where the current state was modeled, and variant 1-4 where 2 minutes of blockade time was added for each variation to model the impact of different blockade times on exhaust emission of vehicles.

4.5.1 Existing State (Variant-0)

The microsimulation models of the existing state produce different results for each location due to variations in traffic volumes, vehicle composition, and road geometry at each location. Figure *4-15* shows the existing emission level of each pollutant at individual locations. The highest emission levels for CO pollutants were measured at B-5 near Serena, with a value of 8430 g/h, while for all other locations, this value was around or below 200 g/h.

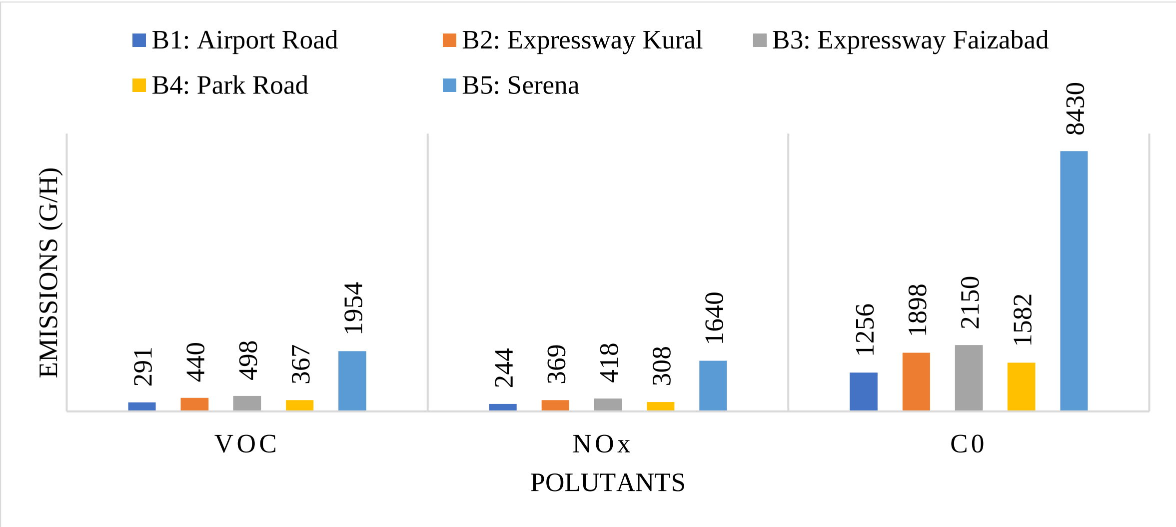


Figure 4-15. Existing emission level at all locations (g/h)

The existing emission level of NOx and VOC was also highest near Serena, similar to CO. At B-5, the quantity of NOx recorded was 1640 g/h and VOC was 1954 g/h, while at all other locations, these values were below 500g/h. This variation in measurement is due to the presence of an existing traffic signal at B-5 near Serena.

4.5.2 Scenario Runs (Variant 0-4)

The simulation results indicate that emissions of all three pollutants increase with the increase in blockade time. **Figure 4-16 to Figure** *4-18* show the variation in emissions of individual pollutants with different blockade time intervals at each location. The x-axis of each figure shows the blockade time, which ranges from zero minutes for variant-0 to 8 minutes for variant-4. The emission of pollutants increased linearly with respect to stoppage time at

Blockades 1 to 5. Sum of individual exhaust emission indicate that as blockade time increases the emissions of blockade B1- B4 rise more sharply as compared to B5.

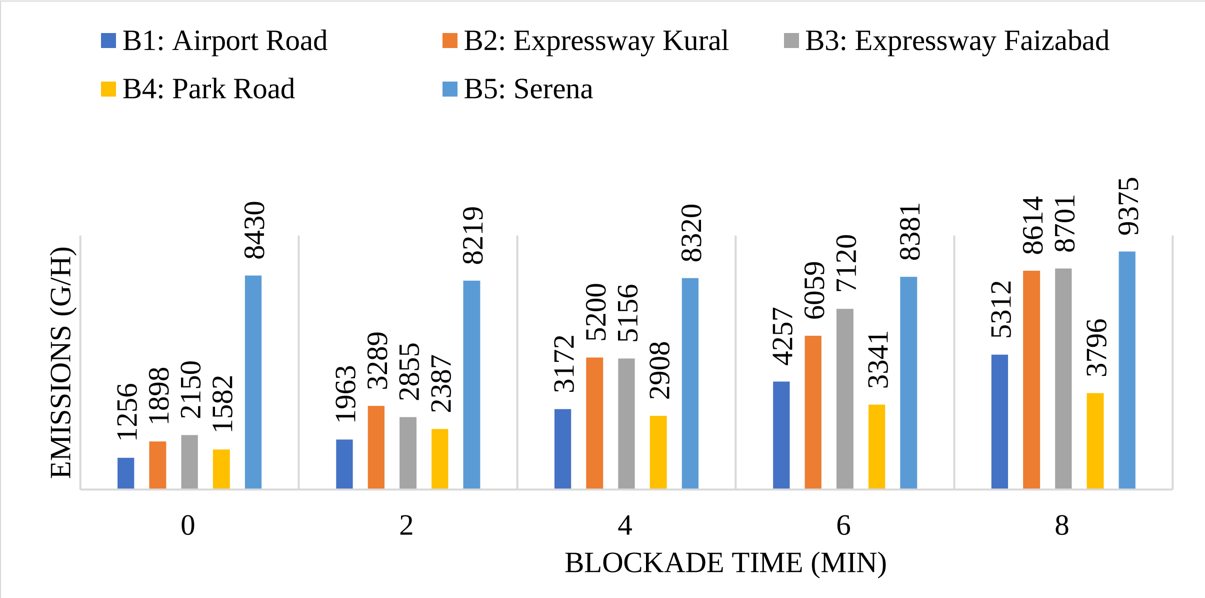


Figure 4-16. CO emissions in all variants (g/h)

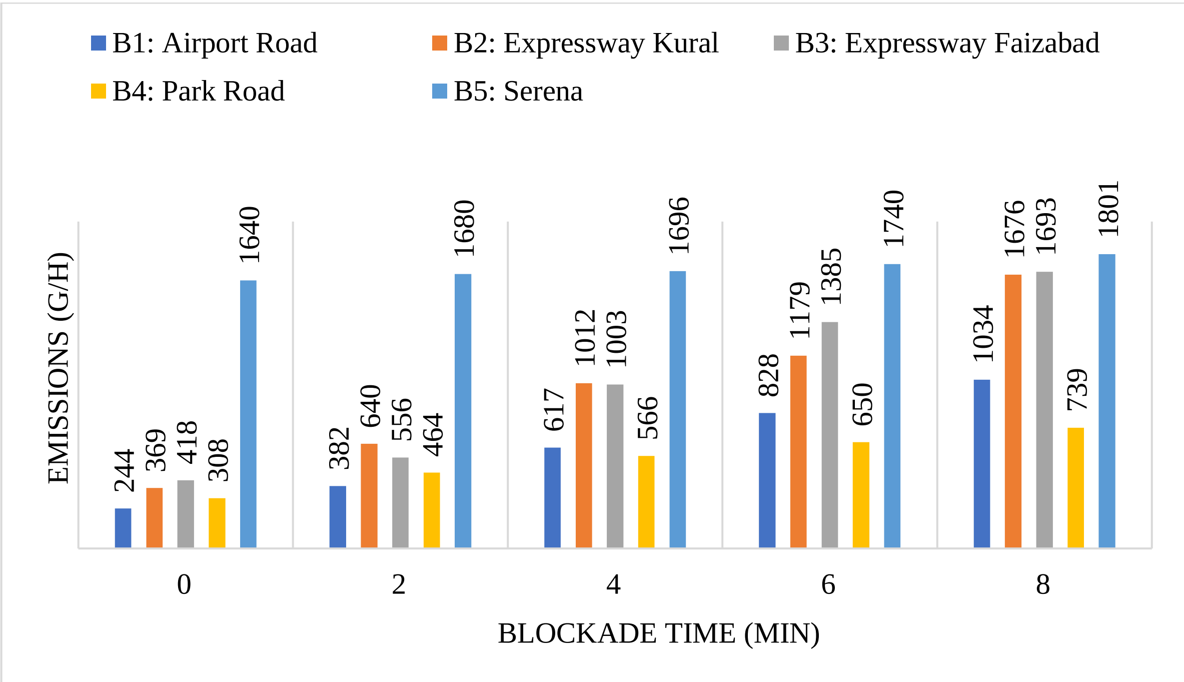


Figure 4-17. NOx emissions in all variants (g/h)

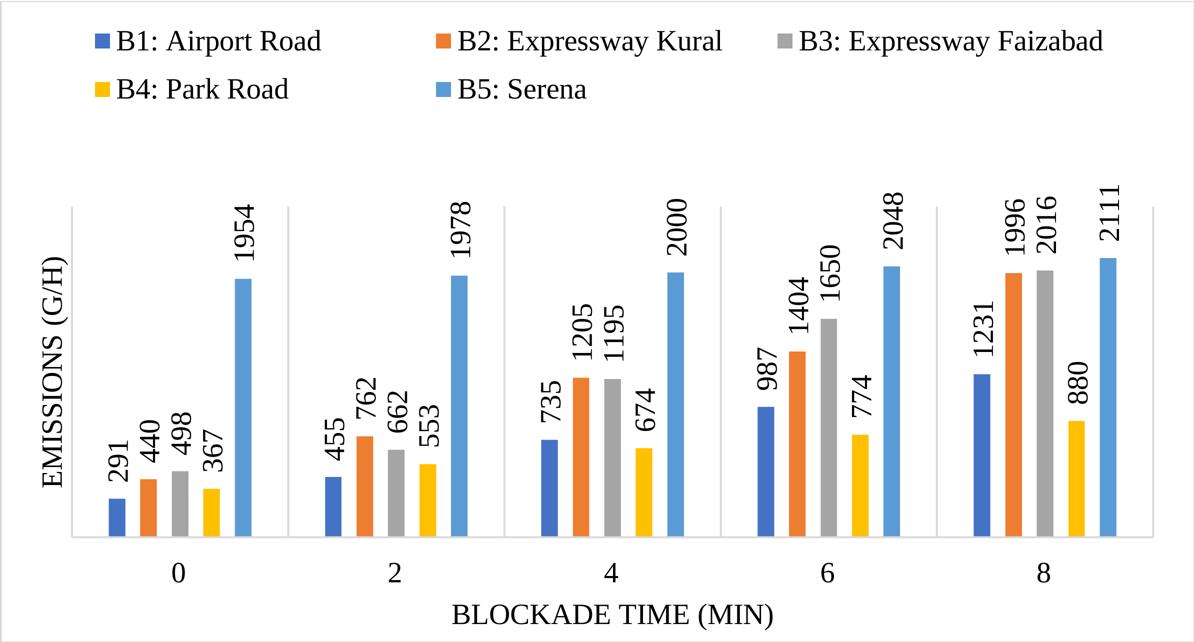


Figure 4-18. VOC emissions of all variants (g/h)

CHAPTER 5: CONCLUSION

This study aimed to evaluate the environmental and economic impacts of road blockages caused by VIP movements in urban areas. This study revealed Travel time and travel cost as the most influential factors affecting mode choice. Gender and income also exerted notable influence. Women were found to have a strong preference for cars over bikes. Interestingly, the choice model revealed that women preferred public transport over cars in the case of VIP movement. Income was also influential in mode choice as the model revealed that individuals with income greater than 60 thousand rupees were most likely to choose cars. The age Variable was not found statically significant in this study. The value of time was determined to be 397 PKR/h (1.77 USD/h), which is similar to the VOT estimated by previous studies [54] and [33]. This suggests that the blockages caused by VIP movements in urban areas have a similar VOT to the congestion experienced in metropolitan cities.

Microsimulation results demonstrated that VIP blockages have a significant negative impact on the environment and transportation system, with exhaust emissions and fuel consumption increasing significantly as blockage duration increases. The exhaust emission analysis also indicated that the emission of harmful pollutants rose more sharply at freeway segments compared to signalized intersections with the increase in blockade time. The percentage increase in total delay cost was 34% for the first two minutes of blockade time. This increase rose to 72% as blockade time increased from two to four minutes. The exponential growth in delay cost and exhaust emissions show the negative impact of VIP Movements on the economy and well-being of road users from developing countries.

A policy implication that can be drawn from this study is to limit road blockages for VIP movements to a maximum of two minutes. Secondly, this study also highlights the need for sustainable transportation policies to discourage private car usage. Overall, this study provides important insights for policymakers to formulate sustainable transportation policies and highlights the value of using various research techniques to analyze complex urban transportation issues.

LIMITATION AND FUTURE RESEARCH

This study only analyzed traffic volume and inventory data during specific rush hours, neglecting variations throughout the day and different seasons. Considering longitudinal data could offer more comprehensive insights into congestion patterns and their impacts. Additionally, the research area was confined to Islamabad and Rawalpindi, limiting the understanding of congestion's economic and environmental effects in Pakistan. Expanding the study to include more cities or regions could provide a broader perspective.

Future studies should assess the health impacts of air pollutants emitted during congestion events, particularly VIP movements, emphasizing the need to address environmental pollution in urban areas. Furthermore, conducting comparative studies among multiple developing countries facing similar congestion issues might reveal common patterns and differences, leading to more effective solutions.

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APPENDIX –I

QUESTIONNAIRE

A DEMOGRAPHICS:

1. Gender
   a. Male   b. Female
2. Age (in years): ______________
3. City of Residence
   a. Rawalpindi   b. Islamabad   c. Both
4. Employment Status:
   a. Self-employed/Business   b. Government/private Employee
   c. Un-employed   d. Student
5. Education Level:
   a. Secondary   b. Matric   c. Graduate/Higher
6. Average Monthly Income: _______________
7. What is your average monthly travel expense? _________________

B. DAILY TRIPINFORMATION

8. Do you own a motor Vehicle?
   a. Yes   b. No
9. If yes, which type of vehicle do you own?
   a. Car   b. Bike
   c. Both   d. I don't own a vehicle
10. What is the purpose of this daily commute?
    a. Work   b. Education
    c. Business   d. Recreation
11. What is your daily mode of commute?
    a. Car   b. Bike   c. Public Transport (Van/Mini Bus)
12. How many people, including you, travel through your selected mode? ______________ (Write an approximate number if you travel through public transport like van or bus).
13. What is the place of origin (residence) of this daily commute? ____________
14. What is the destination (work place, education institute, business etc.) of this daily commute? _____________
15. What is the usual journey time of this commute from your residence to your destination? _____________
16. What time do you usually leave your residence? _________________
17. What time do you usually reach your destination? ________________

18. How much does this one trip (from your residence to your destination) usually cost you? __________
19. How long does it take you to get from your residence to bus stop? (Only answer you use public transport)
20. For how long do you usually wait at the bus station? (Only answer you use public transport)

C. STATED PREFERENCE: In every scenario different modes along with their expected travel time, travel cost and waiting time are mentioned. Please read the scenarios carefully and select your preference.

21. Suppose if you are travelling from Old airport Rawalpindi to Fiazabad Islamabad using airport road and Islamabad expressway which mode will u pick?
    a. Car (Travel Time :25min , Travel Cost:250Rs , Waiting Time: Zero)
    b. Bike (Travel Time :20min , Travel Cost:60Rs , Waiting Time: Zero)
    c. Van (Travel Time :25 min , Travel Cost:50Rs , Waiting Time:20min)

22. Suppose if you are travelling from PWD Rawalpindi to Fiazabad Islamabad using Islamabad expressway which mode will u pick?
    a. Car (Travel Time :30min , Travel Cost:300Rs , Waiting Time: Zero)
    b. Bike (Travel Time :25min , Travel Cost:70Rs , Waiting Time: Zero)
    c. Van (Travel Time :35min , Travel Cost:55Rs , Waiting Time:15min)

23. Suppose if you are travelling from Fiazabad Islamabad to Blue Area Islamabad using Islamabad expressway which mode will u pick?
    a. Car (Travel Time :18min , Travel Cost:150Rs , Waiting Time: Zero)
    b. Bike (Travel Time :15min , Travel Cost:40Rs , Waiting Time: Zero)
    c. Van (Travel Time : 25min , Travel Cost:25Rs , Waiting Time: 5min)

24. Suppose if you are travelling from Fiazabad Islamabad to Sectariat Islamabad using Muree road which mode will u pick?
    a. Car (Travel Time :20min , Travel Cost:200Rs , Waiting Time: Zero)
    b. Bike (Travel Time :25min , Travel Cost:50Rs , Waiting Time: Zero)
    c. Van (Travel Time :30min , Travel Cost:45Rs , Waiting Time:10 min)

D. VIP MOVEMENTS

25. Have you ever encountered road blockages caused by VIP movements?
    a. Yes   b. No
26. If yes, how long was the road blocked by police?
    a. < 5 minutes   b. 5-10 minutes   c. >10 minutes
27. For how long were you trapped in the resulting congestion?
    a. < 5 minutes   b. 5-10 minutes   c. >10 minutes

28. Would you change your travel route or schedule if by an official source about VIP movements?

a. Yes b. No

29. How can we reduce VIP movements?______________________________