POST IMPLEMENTATION EVALUATION OF LAHORE-SHEIKHUPURA-FAISALABAD DUAL CARRIAGEWAY

A thesis submitted in partial fulfillment of

the requirements for the degree of

Master of Science

in

Construction Engineering and Management

Submitted By

Sandeerah Choudhary
(NUST201261012MSCEE15412F)

National Institute of Transportation (NIT)
School of Civil and Environmental Engineering (SCEE)
National University of Sciences & Technology (NUST)
Sector H-12, Islamabad, Pakistan.
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Certified that the contents and form of thesis titled “Post Implementation Evaluation of Lahore-Sheikhupura-Faisalabad Dual Carriageway” submitted by Sandeerah Choudhary have been found satisfactory for the requirement of Master of Science degree.

Supervisior: _____

Associate Professor (Dr. Anwaar Ahmed, PhD)

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To the Holy Prophet ﷺ,

and My Loving Parents.

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"and Allah is sufficient as a friend, and Allah is sufficient as a helper"

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ABSTRACT

The transportation systems generally constitute the largest public-sector investment by any society. Quality and quantity of transportation infrastructure has direct influence on the global competitiveness and economic vitality of a nation. Transportation engineers and planners, policymakers, environmental groups, and the general public are interested in refined procedures of project evaluation. Thus there is a need of best project evaluation practices and monitoring of the expected impacts of alternative investment decisions and other stimuli on the operations of existing or planned transportation systems. Pakistan is a developing country where road infrastructure is the main mean of transportation. Every year hundreds of billions are invested on road infrastructure. Post implementation evaluation of transportation project helps to judge the effectiveness of the project after it has been in public use for some time. Post implementation evaluation can help in quantifying the cost and benefits of the transportation system over its lifecycle. Present study focused on post implementation evaluation of Lahore-Sheikhupura-Faisalabad Dual Carriageway, a four lanes highway that was constructed in 2006 as a BOT (Build-Operate-Transfer) project with a concession period of 22 years. Lahore-Sheikhupura-Faisalabad Dual Carriageway is a 115 Kilometer highway with five toll plazas. Post-implementation evaluation considered four performance criteria: economic efficiency, safety, vehicle operating cost and fuel cost. Post-implementation evaluation was carried out using highway maintenance and rehabilitation strategies proposed by facility operator (LAFCO) and realistic maintenance and rehabilitation strategy proposed in present study. Also, net present value of the project was quantified with and without travel time saving. Study results revealed that project had positive net present value under all scenarios. Using LAFCO maintenance and rehabilitation strategy, project had a travel time savings of Rs. 25.76 Billion safety savings of Rs -0.11 Billion, fuel cost savings of Rs. 3.824 Billion (2007 constant rupees). Also, net present value of toll collection is of Rs. 7.9 Billion (2007 constant rupees). Present research effort shows that BOT projects are economically viable and can be used by highway agencies in Pakistan for development of infrastructure. Also, methodology used in present study can be used by highway agencies for carrying out post-construction evaluation of their projects.

CHAPTER 1

INTRODUCTION

1.1 Background

Safe, efficient, user friendly, economical, fast and easily accessible transportation of people and goods have been a point of concern for all developing countries since decades. The hub of transportation decision making is the appraisal of transportation projects in the framework of available funding. For this reason, the principles and procedures for project evaluation and means of transport are of interest to engineers and transportation planners, administrators and agency transportation, facilities managers and service providers, environmental groups and the general public. Each year, the investment is several trillion dollars worldwide in transportation projects in order to enhance the mobility and transport security and safety, efficiency and economy to stimulate economic development in the system while reducing the environmental, social and economic adverse impacts. Transportation legislation seeks multi-dimensional planning, taking into account various modes and mediums of transportation of goods and services. Additionally, today's transportation lawmaking requires deliberation for all of this as well as the direct, indirect, tangible and intangible infrastructure impacts to the local community, environment and economy, and most importantly to the users. The ever-increasing demands of transportation in major and industrial cities of the world causes numerous problems to the transport network around the globe. Some of the most vital problems include fuel usage and wastage, exhausting travel times, safety of users and adjoining property, environmental deterioration and traffic congestion. To address all these mentioned problems, transportation law making and protocol has emerged from simple planning and management for provisional and federal highway construction and maintenance to planning and preserving complex countrywide multimodal system which helps transportation agencies and providers to keep the road assets in satisfactory condition or to build alternatives in order to offer desirable levels of service in the most effective manner and within the available and cost effective resources and also growth of transportation networks which incorporates undesirable state of congestion, pollution, wastage of resources and time is crucial for rapid national development and urbanization. Basic concepts that are considered in pre and post implementation analysis for road networks are travel time savings, vehicle operating cost savings, air quality impacts and savings, economic efficiency impacts, noise and visual impacts and savings in energy use.

1.2 Problem Statement

Pakistan is the developing country with weak economy. The main source for the transportation of human, freight and services is through road networks. State of the road network is comparable with those of developed countries, but still, there is a huge room of improvement in existing infrastructure and a lot of new networks are need to be developed to meet the standards of developed countries. In the last 20 years, there has been considerable pressure on the development of road infrastructure and road network has proved itself to be the backbone of the transport system in Pakistan. The ever-increasing demands of transportation in major and industrial cities of the world causes numerous problems to the transport network around the globe. Some of the most vital problems include fuel usage and wastage, exhausting travel times, safety of users and adjoining property, environmental deterioration and traffic congestion. Owing to these and other numerous problems associated to the road networks, a post implementation analysis and evaluation framework can be developed to check if the money invested in already developed road networks has benefited the society or not. A case study of Lahore-Sheikhupura-Faisalabad Dual Carriageway with two lanes for each carriageway is considered in this research study to find the applicability of this developed framework. The dual carriageway is one of its type construction and operation project which was completed back in 2006 under the BOT (Build-Operate-Transfer) agreement. The concession period for the project is 25 years. The volume of traffic plying on this road is to tune 30,000 vehicles per day with five toll plazas on the road stretch of 115 KMs to earn back the money invested by constructor and to economically benefit the users in terms of savings in fuel usage, safety and vehicle operating cost. With the help of data available related to traffic volumes before the construction of road and traffic volumes for the period of 8 years after the construction of dual carriageway post implementation study is done which assess the performance of already implemented actions .i. e.; they help to figure out if the implemented alternative performs well and will it continue to function properly over time as it is important for road networks because they are subjected to always changing conditions.

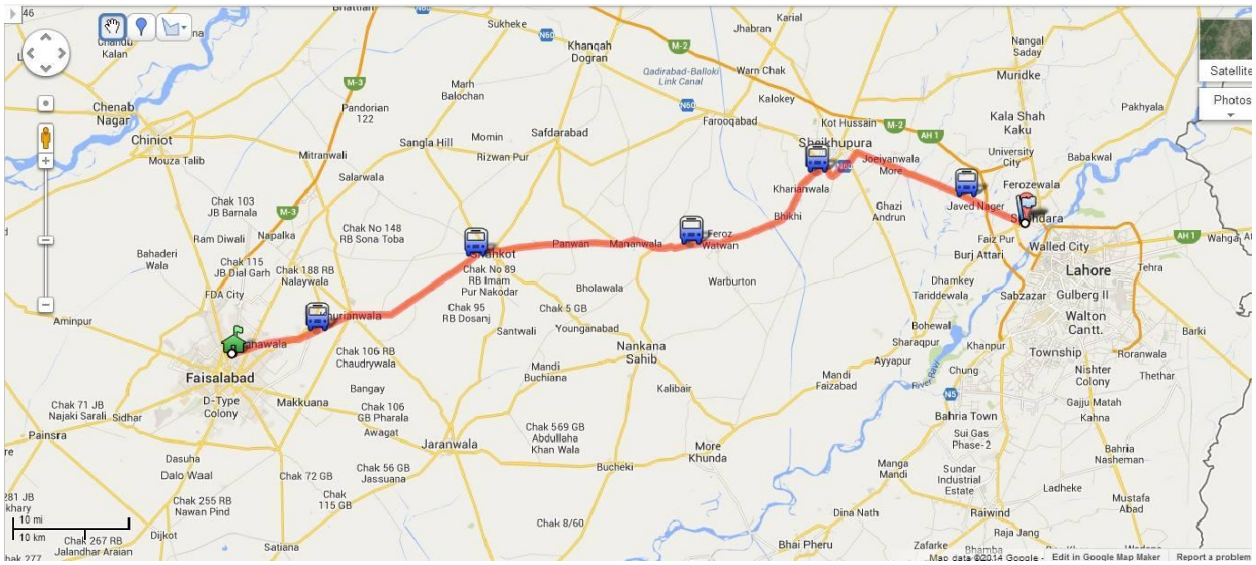

Figure 1.1 Graphical view of Lahore-Sheikhupura-Faisalabad Dual Carriageway

1.3 Research Objectives

Pakistan is the developing country thus efficient road network is crucial for its sustained growth. Following are the identified objectives of this research work:

- To develop a framework for post-implementation evaluation procedures for a highway project
- To demonstrate the applicability of developed framework using a case study

1.4 Scope of Thesis

Pakistan is the sixth most populous country of the world and by 2030, Pakistan will be a massive home to 130 million urbanites. The movement of masses among various areas for transporting freight and services is a general trend. This research will highlight the complex nature of transportation planning procedures and policies and will represent systematic model that can help planners and engineers. The study aims to produce an engineering and scientific comparison of various costs and benefits associated with road agency and users of the facility. The study will also draw a framework for post-implementation analysis by demonstrating the procedures that have already been developed for calculating the impacts and benefits mentioned above.

1.5 Overview of Study Approach

To accomplish the research objectives, a methodology was devised and the following research tasks were outlined:

- Detailed literature review of the post implementation methodologies and their associated factors like travel time, safety, fuel and economic efficiency.
- Collection and collation of data of Dual Carriageway form Lahore-Sheikhupura-Faisalabad Road Network.
- Estimation of future values of Consumer Price Index and Demand.
- Estimation of travel time savings and their monetary values
- Calculations of safety and fuel cost savings due to the addition of an intervention to the national assets.
- Scheduling of operation, maintenance and rehabilitation and options available for this purpose.
- Economic Efficiency Analysis and Discussions.
- Conclusions and recommendations.

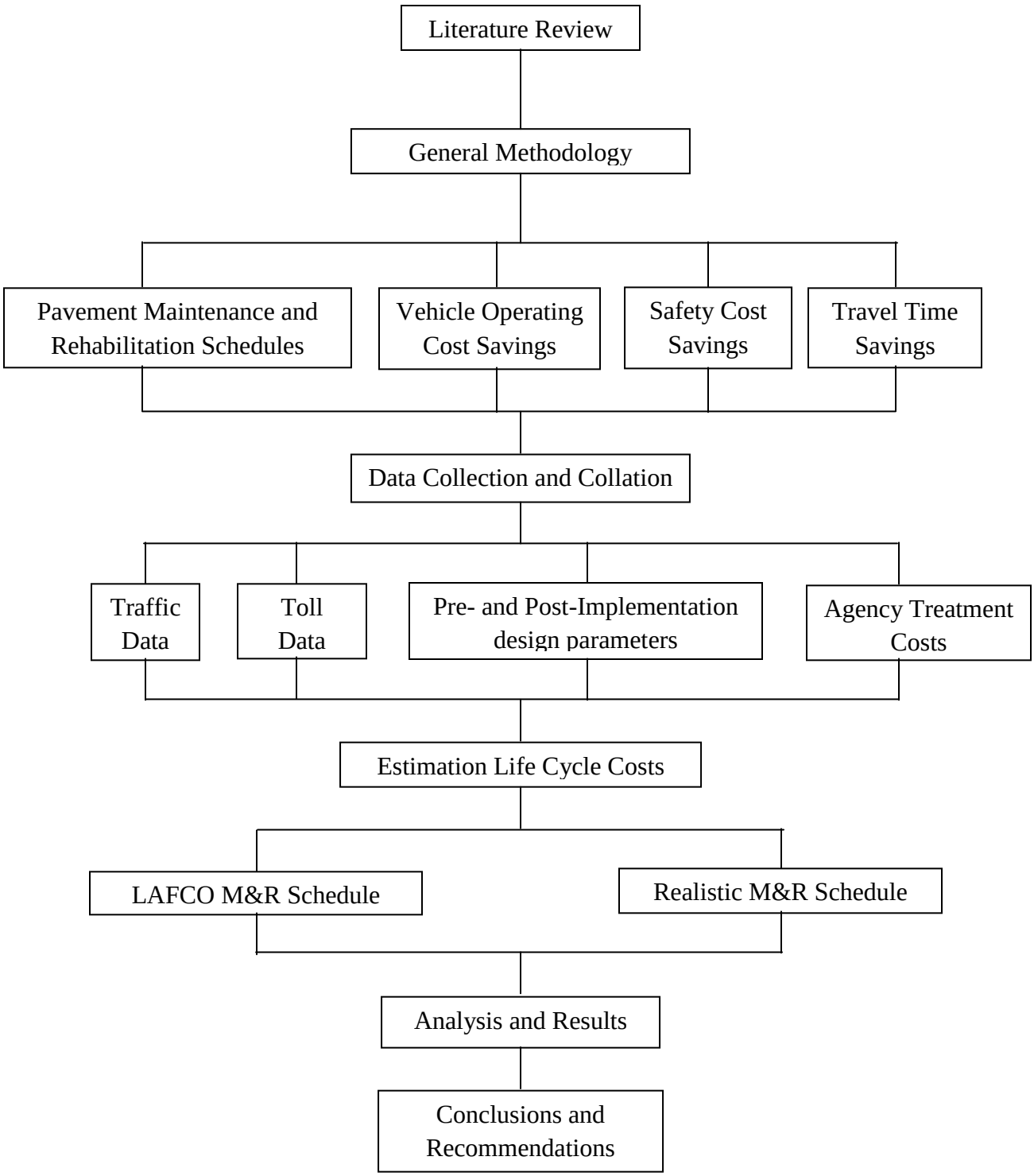

Figure 1. 2 Overview of Study Approach

1.6 Thesis Organization

This thesis is prepared into five (05) chapters. Chapter 1 comprises of concise background of transportation infrastructure in Pakistan. It also highlights the introduction of pre and post-implementation analysis and evaluation procedures and introduces the case study of Faisalabad-Sheikhupura-Lahore Dual Carriageway. Chapter 2 includes detailed literature review of benefits a transportation intervention offers. Travel time savings, safety savings, and vehicle operating costs savings, environmental impacts are discussed. Chapter 3 describes the Methodology and research plan. It enlists all the methods to be used for the calculations of travel time savings and monetary values of these savings, safety savings, savings in vehicle operating costs and at the end economic efficiency of the project and its procedure. All the graphs, tables and appendixes that are used for the calculations of above mentioned benefits are also given in this chapter. Chapter 4 covers the analysis portion. Discussion of the results benefits is also included in this chapter. Overview of economic benefits is shown both graphically and in tabular form. Chapter 5 includes the findings and conclusion about the case study and benefits, construction industry of Pakistan can achieve from BOT contract agreement are also mentioned.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Several studies on pre- and post-implementation analysis have been carried out and several principles and procedures have been established for the calculations of Travel Time, Safety, Vehicle Operating Costs and environmental impacts of an improvement. This chapter is a review of the researches and studies already carried in the past related to post implementation analysis and evaluation of transportation enhancements and new transport networks. Also, it discusses different procedures that are used to calculate the benefits of travel time, safety and vehicle operating costs of the subject road network extended from Faisalabad to Lahore through Sheikhupura.

2.2 Travel Time Impacts

There is a famous saying "Time value of money". To support the statement, Time is an unchangeable entity, can neither be bought nor sold so time has its own value in terms of its productive utility. So a travel time saving can be defined as a time that can be spent by road user in producing some valuable good or service. Travel-time saving is the principle and financially viable benefit attributed to urban transportation project. 80% of the quantified benefits are the travel time savings for transportation Cost Benefit Analyses (CBA) in the United Kingdom (Mackie et al., 2001). A conference of European Ministers of Transport in Paris in December 2003 concluded that "the valuation standards of time requirements for transport and time savings as a consequence of transport policies are often decisive for the acceptance or rejection of transport policies and transport infrastructure investment projects" (Gudmundsson, 2004). Research results indicate that regardless of the method of travelling, people generally attach a higher degree of desirability (and thus, not to benefit the largest and highest value of the time) to the time spent waiting in the car compared to time spent waiting for the vehicle at stop (Mohring et al., 1987).

Travel Time is primarily the function of two components speed and distance. People always want to choose routes that have higher mobility for free flow travelling and avoid congested, time consuming routes over large geographic catchments.

There are many methods that have been developed for finding the speed on different types of road section. COMSIS and HCM are the most commonly used methods for the calculation of speed. Another method, Bureau of Public Roads Function (BPR) is also available that directly estimates the travel time.

The average speed of vehicles can be find on any highway using the HCM method which describe the speed as the function of Peak direction volume to capacity ratio, signal density and highway class (Class I or II Urban Street). Given below Exhibit 15-8 and Exhibit 15-9 can be used to calculate the average speed on any Urban street class.

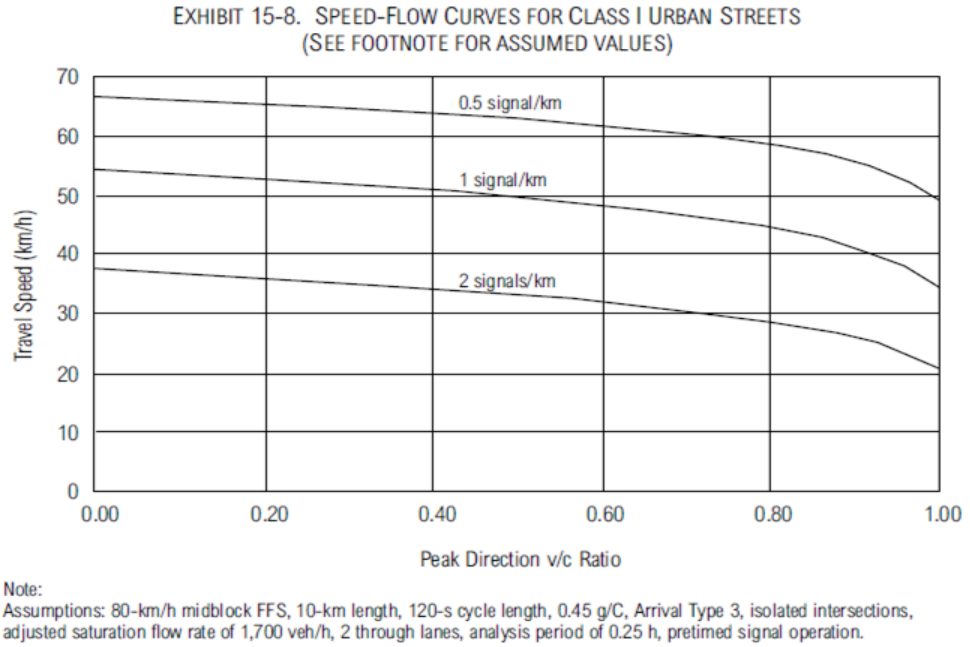

Figure 2.1 Speed-Flow Curves for Class I Urban Streets (Manual, 2000)

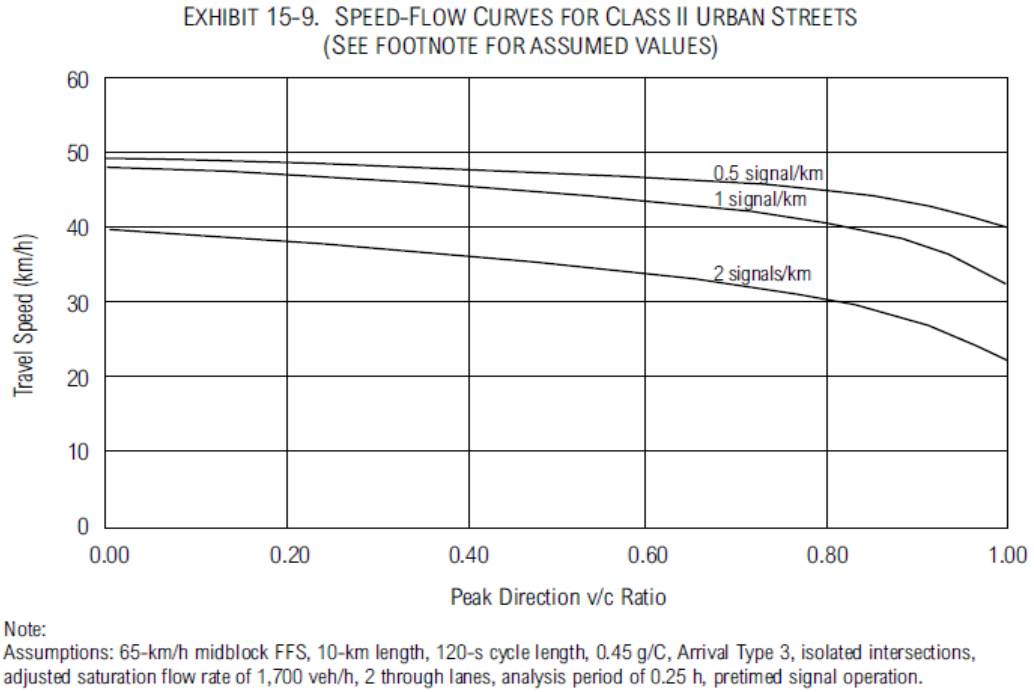

Figure 2.2 Speed-Flow Curves for Class II Urban Streets (Manual, 2000)

COMSIS Corporation also provides a method to calculate the speed under the congestion effects. This method uses a table that was prepared for different hours of the day. The main input is the AWDT to Capacity ratio. The table is given below.

Table 2.1 COMSIS Table for Freeway Speeds (COMSIS-Corporation, 1995)

Hour	Ratio of Average Weekday Daily Traffic to Capacity															
Ending	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
12 mn. –1 a.m.	59.94	59.89	59.84	59.78	59.72	59.67	59.61	59.55	59.49	59.43	59.37	59.3	59.22	58.96	58.65	58.27
1–2 a.m.	59.97	59.94	59.9	59.87	59.84	59.8	59.77	59.74	59.7	59.66	59.64	59.6	59.55	59.3	59	58.65
2–3 a.m.	59.97	59.95	59.93	59.9	59.87	59.85	59.82	59.8	59.77	59.75	59.72	59.7	59.67	59.42	59.13	58.78
3–4 a.m.	59.97	59.95	59.93	59.91	59.88	59.86	59.84	59.82	59.8	59.78	59.77	59.76	59.73	59.5	59.21	58.87
4–5 a.m.	59.96	59.93	59.89	59.86	59.82	59.78	59.75	59.71	59.69	59.66	59.64	59.63	59.59	59.35	59.06	58.71
5–6 a.m.	59.89	59.8	59.69	59.58	59.47	59.35	59.23	59.12	59.01	58.91	58.8	58.69	58.57	58.29	57.98	57.66
6–7 a.m.	59.7	59.41	59.08	58.73	58.37	57.98	57.56	57.15	56.73	56.25	55.69	54.99	53.83	52.51	50.16	48.57
7–8 a.m.	59.54	59.09	58.56	57.99	57.37	56.73	55.93	54.28	50.56	45.38	40.77	36.86	33.74	30.01	27.34	25.3
8–9 a.m.	59.65	59.33	58.94	58.54	58.11	57.66	57.09	55.52	50.75	43.57	37.21	31.99	27.87	24.56	22.23	20.58
9–10 a.m.	59.74	59.49	59.21	58.92	58.6	58.28	57.94	57.53	56.1	51.18	42.26	33.4	27.54	24.01	21.74	19.98
10–11 a.m.	59.74	59.5	59.22	58.93	58.62	58.3	57.97	57.61	57.2	56.43	53.15	44.21	33.55	27.24	23.88	21.31
11–12 md.	59.72	59.46	59.16	58.84	58.51	58.16	57.79	57.4	56.97	56.51	55.73	52.24	42.13	32.77	26.97	23.04
12–13 p.m.	59.71	59.43	59.12	58.78	58.43	58.06	57.67	57.26	56.82	56.35	55.83	54.14	47.63	38.06	29.75	24.01
13–14 p.m.	59.7	59.42	59.1	58.76	58.39	58.01	57.62	57.19	56.73	56.24	55.69	54.42	50.14	41.55	31.6	24.47
14–15 p.m.	59.67	59.35	58.99	58.6	58.2	57.76	57.31	56.83	56.34	55.79	55.02	53.21	48.32	40.17	30.24	23.18
15–16 p.m.	59.59	59.2	58.74	58.26	57.73	57.17	56.59	56.00	55.32	54.17	51.64	46.85	40.12	32.39	24.88	19.91
16–17 p.m.	59.52	59.06	58.52	57.92	57.29	56.62	55.8	54.49	52.00	47.41	40.97	34.47	28.87	23.98	19.7	17.11
17–18 p.m.	59.52	59.06	58.51	57.91	57.27	56.59	55.54	53.38	48.91	42.11	34.96	28.97	24.31	20.74	17.79	16.12
18–19 p.m.	59.67	59.35	59	58.62	58.2	57.78	57.14	55.59	51.35	43.65	35.04	28.17	23.3	20.01	17.40	15.91
19–20 p.m.	59.77	59.55	59.31	59.05	58.78	58.49	58.2	57.85	56.99	53.65	45.43	34.53	26.26	21.79	18.37	16.34
20–21 p.m.	59.82	59.65	59.46	59.26	59.05	58.84	58.62	58.39	58.15	57.77	55.98	49.27	37.48	28.67	22.29	18.19
21–22 p.m.	59.83	59.68	59.51	59.33	59.14	58.95	58.75	58.54	58.29	58.02	57.71	56.74	52.66	43.71	32.53	23.25
22–23 p.m.	59.86	59.74	59.6	59.46	59.31	59.16	59	58.82	58.61	58.39	58.18	57.92	57.33	54.59	46.24	32.38
23–12 mn.	59.9	59.81	59.71	59.6	59.49	59.38	59.27	59.14	58.99	58.83	58.68	58.52	58.33	57.79	55.68	45.68
Peak[b]	59.59	59.2	58.74	58.24	57.71	57.14	56.39	54.88	51.27	45.16	38.26	32.07	27.27	23.52	20.57	18.69
Off-peak[b]	59.74	59.5	59.21	58.92	58.6	58.27	57.92	57.56	57.12	56.38	54.57	50.31	43.23	36.4	30.20	25.44
Daily	59.68	59.37	59.02	58.64	58.23	57.8	57.28	56.43	54.58	51.24	46.62	41.11	35.3	30.31	25.95	22.71

[a] Free-flow speed of 60 mph assumed in simulation.
[b] Peak period (7:00–10:00 a.m.); off-peak period (4:00–7.00 p.m.)

2.3 Safety Impacts

According to Pakistan Bureau of Statistics, number of accidents in Pakistan has declined from 10466 in 2006-07 to 8898 in 2012-13 among which 3884 were deadly and 5104 were non-fatal. For Punjab, number of accidents in 2012-2013 was 4587 among which 2213 were fatal and 2374 were non-fatal. Economically, it is expected that the cost of road traffic injuries in 1% of gross national product (GNP) in low-income countries, 1.5% in middle-income countries and 2% in high-income countries (Söderlund and Zwi, 1995). The economic cost of road crashes and injuries is estimated to be over Rs100 billion for Pakistan (Hyder, 2000). In Pakistan rate of road traffic injuries was 15 (including minor injuries) per 1,000 persons per year (Ghaffar et al., 2004). Other facts and figures show that there are 1.24 million road crash fatalities and 20-50 million non-fatal injuries occur per annum. Road side accidents contribute 3,400 deaths and 82,200 non-fatal injuries each day out of which 90% occur in low- and middle-income countries. Projecting the issue shows that it would be 5th leading cause of death by 2030 and the total

economic cost of these exceeds over 100 billion $ annually. Due to advancement in technology trend shows that the road accidents are decreasing in developed countries and increasing in developing and under developed countries.

Facts about Pakistan reveal that there were 1.4 million road traffic crashes occurred in 1999 (NTRC) and 2 million crashes occurred in 2006 (NRSS). According to Police department reports, there were 5,323 deaths were registered in 2012 and WHO (World Health Organization) claims that there were 30,000 road crash fatalities in 2013. Police department also reported that there were 13000 injuries in 2011. Ghaffar stated that there were 1,500 injuries per 100,000 population (Ghaffar et al., 2004) and Fatmi et al. (2007) reported 270,000 injuries per 100,000 population. There were 34000 Injury Prevention Centers in Karachi by 2012 and the number is still growing.

Road Crash Injuries are the second leading cause of disability and the fifth cause of overall healthy life-year losses. This is the eleventh cause of premature fatality in Pakistan. Total economic cost of road crashes exceeds over 6 billion $ annually. Main victims of RCF and RCI are the young men aged 15 - 45 years. Pedestrians and motorcyclists accounted for the majority of RCF, with commercial vehicles being the most common striking vehicle.

Highway Safety Engineering is element of Traffic Engineering which studies the reduction in the rate of recurrence as well as harshness of crashes. It uses physical characteristics of vehicles, vehicle dynamics, road user psychology and other human factors like driver age, experience, eyesight etc., in order to minimize the effects of factors that contribute to the road crashes. Transportation projects directly or indirectly considers safety factor that reduces the rate and severity of crashes. As such, encouragement of safety is considered to be the key feature of the user associated benefits with the physical and policy changes in the transport system. And the economic cost of transport accidents is directly borne by individuals, insurance companies, government, and they directly affect market productivity, property damage, and household productivity and labor costs. Within the road network safety problems are the most deadly specially at roads in rural areas and on roads that have only one lane in each direction. The costs of crashes can be very high. Most of these roads were designed and built many decades ago using standards that now are outdated. As such, they are generally characterized by operational and safety deficiencies arising from inadequate road geometry, driver information deficiencies,

lack of passing opportunities, and traffic conflicts due to driveways. Transportation projects usually include interventions to enhance these services to satisfactory values.

2.3.1 Crash

The basic unit for measuring transportation safety is a crash. A crash is the accident involving at least one moving vehicle i. e.; car, truck, plane, boat, railcar, etc. with any other moving or still vehicle or object (Sinha and Labi, 2011). Transportation crashes are characteristically subjective to factors such as driver, pilot, or operator error, mechanical failure, and poor design of the road way, waterway, railway, or runway. A crash can also involve non collision off the transportation path, such as a vehicle rollover. Engineering factors involved in a road crash are as shown in figure 2.3.

Figure 2.3 Engineering Factors of Highway Transportation Crashes (Sinha and Labi, 2011)

2.3.2 Classification of Transportation Crashes on the basis of Severity

On the basis of severity transportation crashes are classified into three categories:

a) Fatal Crash is a crash which includes at least one fatality.
b) Injury Crash is which includes a non-fatal injury.
c) Property-Damage-Only crash is that includes a loss to the transporting vehicle and sometimes to property, but no injury or fatality has occurred (Sinha and Labi, 2011).

2.3.3 Categories of Factors Affecting Crash

The factors that affect the frequency and severity of the transportation crashes are environmental, engineering, policy, driver characteristics, vehicle type and enforcement laws etc.

a. **Environmental Factors:** Environmental surroundings such as low lights, poor visibility, high winds, rain and snow falling and hailing, ice on a roadway or runway or on airplane wings, animals crossing the highway are important factors contributing to transportation crashes.

b. **Engineering Factors:** Adverse roadway geometry situations e.g; Dimensions, vehicle configuration, Sight distance and topographic characteristics e.g; Steep grades, sharp curves and turns, mountain passes often causes frequent crashes. In addition, the poor condition of roadway like deteriorated, deformed and cracked and bumpy surface elements also aid the crashes.

c. **Policy Factors:** Recently the national policies like seriousness of laws for drivers, 10-hours a day truck driving is the maximum limit for truck drivers, seat belt use and helmet use and their strict execution have improved the safety conditions.

d. **Driver Characteristics:** Crashes can also be influenced by the drivers, pilots or operators characteristics like age, gender, mental and physical conditions, sobriety, experience as well as alcohol or drugs.

e. **Vehicle or Mode Characteristics:** Vehicle design features also severely affect crash frequency and severity. Differences in size, weight, and shape in a traffic stream can increase the likelihood of collisions. Moreover occupants in light vehicles are more vulnerable to fatalities as compared to heavy vehicles.

f. **Enforcement Factors:** The frequency of patrols and the establishment of effective driver education and licensing restrictions generally help to improve safety. Moreover high penalties for traffic infractions generally tend to encourage the driver's/operator's responsibility and so can increase traffic safety.

2.3.4 Crash Cost Distribution:

The crash costs are widely scattered. Some are borne directly by the passengers travelling in the vehicle that experienced a crash are involved in a crash and so is the internal cost. Moreover; there are other costs known as Insurance and External costs. The distinction between internal and external costs is important for assessment of the overall effectiveness, efficiency and equity of

crash compensation and traffic safety measures. The distribution is clearly shown in the table below as,

Table 2.2 Traffic Crashes and associated Cost Distribution (Sinha and Labi, 2011)

Distribution	Monetary	Non-Monetary
Internal	Safety equipment costs, uncompensated damages, insurance deductibles borne by the motorists involved in a crash.	Uncompensated pain and lost quality of life borne by the motorists involved in an accident.
Insurance	Damages and lost income compensated by insurance.	Pain, grief and lost quality of life remunerated by indemnity.
External	Uncompensated reimbursement borne by pedestrians; crisis response and crash prevention programs, reduced walking.	Irreplaceable pain, woe and lost quality of life borne by pedestrians.

2.4 Vehicle Operating Cost Impacts

Vehicle costs are direct expenses that comprise the costs of vehicle ownership known as fixed cost and vehicle operation costs known as variable costs. Vehicle operating costs are the basic component transportation costs and they vary with vehicle life, usage, condition and its expanses like maintenance of the vehicle, it's cleaning and repairing and majorly fuel consumption and is typically expressed in cents per mile traveled by a vehicle.

2.4.1 Components of VOC

Major factors that directly affect vehicle operating costs are enlisted as;

a. Consumption of fuel and oil,
b. Tire wear and tear,
c. Vehicle maintenance and repair.

2.4.2 Factors Affecting Vehicle Operating Costs

The following factors affect vehicle costs:

a. Vehicle Type: Ownership and operating costs vary by vehicle size, class, and other characteristics. Heavy vehicles like trucks, trolleys etc typically have much higher vehicle costs than light vehicles.

b. Vehicle Speed: Vehicle speed is the most dominant factor influencing vehicle operating costs. Trend of vehicle speed and operating costs reveals that operating costs generally

decreases with increasing speed to a certain point, and then begin to increase with increasing speed.

c. **Speed Variation:** Frequent changes in speed increase vehicle operating costs and this is higher when speed varying occurs at higher speeds.
d. **Road Grades:** Topography of land can either be uphill (positive) or downhill (Negative). Positive grades are more energy and fuel demanding. This leads to an increase in operating costs. Negative grades may reduce operating costs because they release engine force but increases wear on brakes.
e. **Curves:** A highway curve requires a greater amount of energy from a vehicle to counter the centrifugal force. This also causes additional wear on the vehicle's tires thus leading to an increase in operating costs.
f. **Road Surface:** The roughness of the road surface can influence vehicle operating costs by affecting rolling friction. Rough surfaces can lessen speed, need greater fuel consumption, increase wear on tires, and increase maintenance costs.

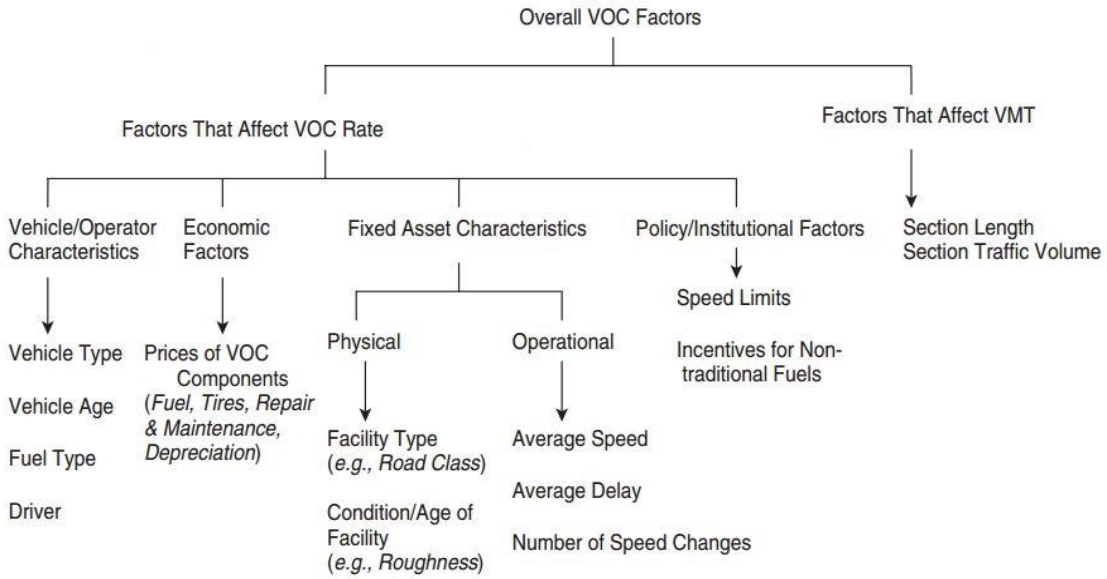

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Figure 2.4 Factors Affecting Highway Vehicle Operating Cost (Sinha and Labi, 2011)

The last comprehensive study of vehicle operating costs in the United States was reported by Claffey in 1971. This work and other information were used by Winfrey to prepare a comprehensive set of vehicle operating cost tables. These two studies are the basis for most vehicle operating cost calculations performed by highway agencies. Vehicle operating costs

include consumption of fuel/oil, replacement of tyre due to wear and tear, vehicle maintenance and repair etc. Fuel consumption is having lion share of 50% - 75% in vehicle operating costs.

2.5 Economic Efficiency Analysis

The costs for constructing road networks and interventions, and maintenance consume a large proportion of national budgets but the costs borne by the road users for vehicle operation and depreciation are even greater. Hence, it is important for the policy makers to consider total transportation costs. This requires quantitative methods for predicting performance for performing pre-implementation analysis and to choose among the best of all possible alternatives and costs of both roads and vehicles over large and diverse road networks, and under various investment and management policies and strategies. The World Bank initiated a study in 1969 which later became a large-scale program of collaborative research with leading research institutions and road agencies in several countries. This Highway Design and Maintenance (HDM) Standards Study focused on the rigorous empirical quantification of tradeoffs between the costs of road construction, road maintenance and vehicle operation, and also on the development of planning models incorporating total life-cycle cost simulation as a basis for highway decision- making (Riley et al., 1994). The USDOT (2005) reported that every $1 billion invested in transportation infrastructure generates more than $2 billion in economic activity and creates up to 42,000 jobs. It has been estimated that highway construction directly generates an average of 7.9 jobs per $1 million spent (1996 dollars) on construction (Keane, 1996); public transportation directly supports an average of 24.5 jobs per million passenger-miles; and air transportation supports as many as 1000 on-site jobs per 100,000 annual passengers, depending on site-specific factors (Weisbrod and Weisbrod, 1997).

CHAPTER 3

RESEARCH METHODOLOGY

This chapter focuses on the discussion of principles and procedures used to calculate the benefits from an intervention. Besides these, models that are used for calculations along with their assumptions and limitations are given. Graphs and tables used for interpolation, extrapolation and predictions are also given. Appendixes are attached for detailed overview of procedures. This research also focuses on the fact that all these graphs, tables, models, appendixes are not applicable to the transport environment of Pakistan. This chapter also discusses how alternatives are used to calculate results viable to local conditions.

3.1 Research Plan

To access the economic performance of Faisalabad-Sheikhupura-Lahore Dual Carriageway, data was obtained from the LAFCO Office. Certain assumptions were made for the incomplete data and calculations were done to investigate the economic benefits of the facility to the two main industrial cities of Pakistan. From calculations, results were drawn about the benefits and conclusions were made.

3.2 Research Methodology Framework

The whole working of the calculations is portrait in the following section.

Traffic data from LAFCO for the period of 2008 to 2014 is given in appendix A. Also the Toll Plaza wise traffic count is also given in appendix B. From the data given, first task is to estimate the future traffic volumes to make further calculations.

3.3 Demand Estimation

One of the key aspects in process of assessing the transport system, estimation of demand that provides a basis for predicting the needs of the initial intervention in terms of the transport of passengers and goods, vehicles and storage units that are expected to use the facility is necessary. These predictions are more important in the evaluation of various transportation alternatives in every stage of development to improve the system. And to go ahead with any decision transport facility it is more governed by the level of its anticipated use, while at the design stage, and sizing of the proposed transport and operational policies of the proposed facility are more likely

to be affected by the expected levels of demand. Furthermore, decisions making to select and implement any system policies are influenced by expected levels of trip making.

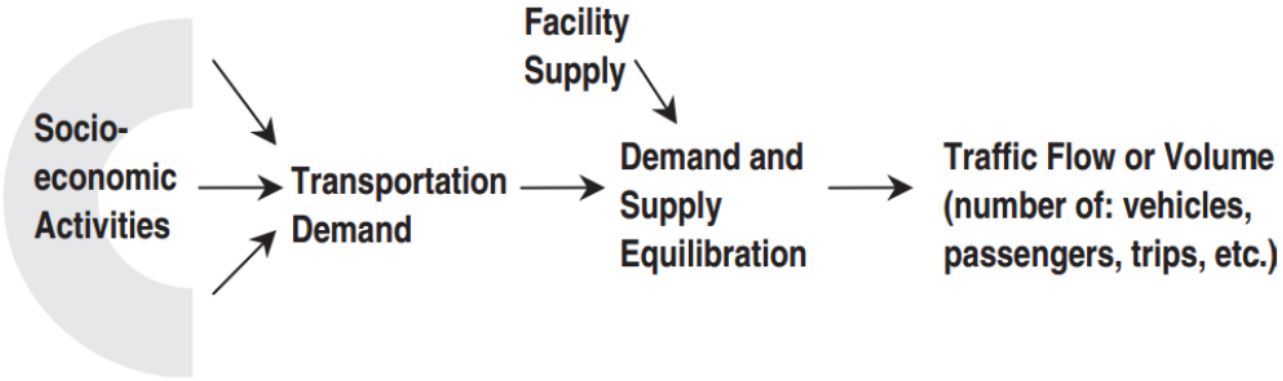

Figure 3.1 Factors Affecting Traffic Volume (Sinha and Labi, 2011)

From the traffic data given for the first eight years of the level of the service .i .e; 2008 to 2014, following trend line is achieved;

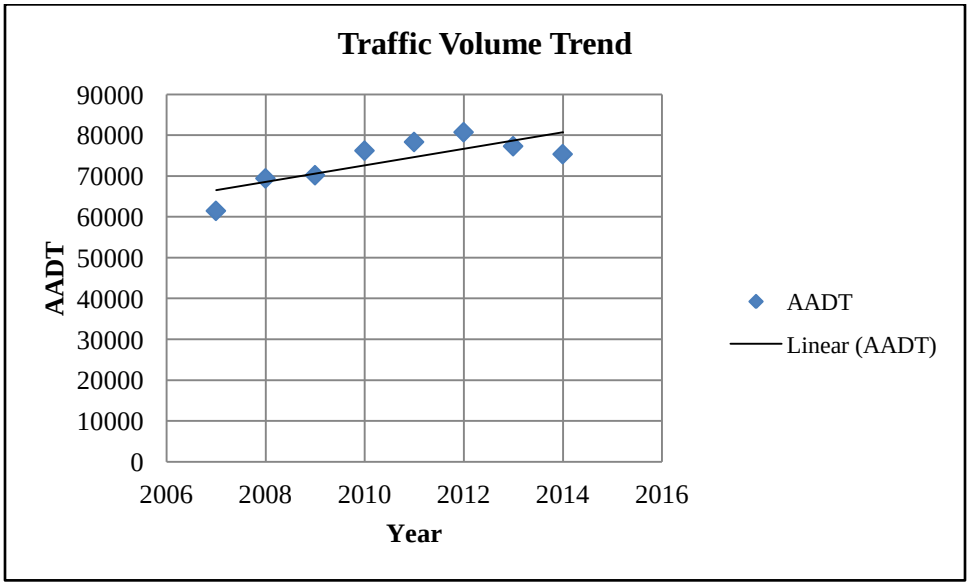

Figure 3.2 Traffic Volume Trend

Traffic volumes for the whole road sections are as; 61495, 69445, 70229, 76245, 78372, 80762, 77333 and 75388 respectively from 2008 to 2014. From the graph, no general trend in Annual Average Daily Traffic (AADT) is found so a constant increase of 4% annual traffic

growth is considered for calculation purpose. Using this assumption, AADT is predicted for the life time of the facility as given in appendix C.

All the calculations for travel time and vehicle cost savings are done for the Light Vehicle Traffic and Heavy Vehicle Traffic separately, so AADT for light and heavy traffic is found and given in Appendix C.

3.4 Forecasting of CPI

The next basic component for calculating the benefits is the Consumer Price Index. CPI is an index of variation of prices for retail goods and other items over time. CPI cannot be predicted beforehand but for the sake of calculations, CPI values are forecasted using the CPI values since 1960 for the life time of the road intervention as given in Appendix D.

In the first step, CPI from 1960 to 2013 is found from the Bureau of Statistics, Pakistan and the trend is plotted. From the trend line, it is known that exponential relationship exists for CPI values and using the equation, future values are predicted as shown in Table 2 of appendix D.

3.5 Calculations of Benefits

The basic components of benefits an intervention can offer are Travel Time Savings, Vehicle Operating Cost Savings, Safety Savings, Environmental Impacts, and Economic Impacts. In this study we consider all the benefits except the environmental benefits to the society.

3.6 Travel Time Savings

Travel time saving can be defined as time that can be saved using an intervention and it can be invested by the road user to make money, goods or services. Given below are the detailed procedure framework that is to be used for the calculation of travel time saving and its monetary value.

HCM Method is used for the calculation of travel time saved before intervention because it also encompasses the rural roads and it describes the speed as the function of peak direction volume to capacity ratio, signal density, flow rate, free flow speed and highway class. COMSIS method is used for the calculation of savings in travel time after intervention as it is for the urban expressways, which describes the speed as the function of demand and capacity. This method,

for the calculation of speed, requires the input AWDT/Capacity and the time of the day. For the results to be conservative, speed is calculated for the peak hour times.

For the calculation of savings in travel time (minutes), following data and assumptions are used. Free Flow Speed for the before intervention case is taken to be 75Kms/hr for Light Weight Traffic and 65Kms/hr for Heavy Weight Traffic. These values are taken from the road signs installed on the road section before the construction of intervention. For the calculations after intervention speed of 100Kms/hr for Light Weight Traffic and 90Kms/hr for Heavy Weight Traffic is considered. These are the design speeds for the road network after intervention. Using the free flow speed, capacity can be predicted from the table. So, before intervention capacity is taken to be 1800 (veh/hr/lane) and after intervention it is considered to be 2100 (veh/hr/lane). AWDT is considered to be 11 times the AADT. From these observations and assumptions, volume to capacity ratio is calculated. Volume is taken to be equals to AWDT. From this calculated ratio, speed of vehicle on road is found from the exhibit 15.8 given the previous chapter. For the improved after intervention case, AWDT/Capacity is found and then speed for the peak hours is approximated from the table 5.1 as given in previous chapter. The speed calculated from graphs and tables as described are used to calculate time using the following relationships

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}} \tag{3.1}$$

and;

$$\text{Time} = \frac{\text{Distance}}{\text{Speed}} \tag{3.2}$$

From the time calculated above, one minute is added to each time taken to counter for the waiting time at the toll plazas. After time calculation, cost of time saving is calculating using the following procedure;

Saving in travel time is find using the formula;

$$\text{Savings (minutes)} = \text{Travel Time before intervention} - \text{Travel Time after intervention} \tag{3.3}$$

Find the number of vehicles of each type from the data and calculate the equivalent number of persons travelling known as the occupancy rate. Light weight vehicles include cars

and wagons where as heavy weight vehicles include Bus upto 30 Seats, Bus, Mini Truck, Truck 2/3 Axle, Trolley Agri Goods, Tractor with Container and Multi Axle Trailer. Also the number of persons is calculated as;

Table 3.1 Vehicle Type and Corresponding Number of Equivalent Persons

Sr #	Vehicle Type	Number of Equivalent Persons
1	Cars	1.5
2	Wagons	18
3	Bus upto 30 Seats	25
4	Bus	35
5	Mini Truck	2
6	Truck 2/3 Axle	2
7	Trolley Agri Goods	2
8	Tractor with Container	2
9	Multi Axle Trailer	2

The travel time saving contributes the value of an hour of each person using the road. From the survey, it is assumed that the value of an hour of person traveling in a car is 295 (2014 constant) rupees and value of one hour of person travelling in any other vehicle is 202 (2014 constant) rupees. LAFCO Project was completed in 2006 and started gaining benefits from 2007 so, 2014 constant rupees need to be converted to 2007 using the CPI index and the formula given as;

$$\text{Cost}\,(2007)=\text{Cost}\,(2014)\,\frac{\text{CPI}\,(2007)}{\text{CPI}\,(2014)} \tag{3.4}$$

Using the formula, time worth of every person traveling in a car is 135 Rs/hr in 2007 and time worth of every person traveling in a car is 92.47 Rs/hr in 2007. Total savings can be calculated using;

$$\text{Cost} = \text{AADT} * \text{Occupancy rate} * \text{Value of one hour of time (2007 const. rupees)} * \text{Travel Time Saving (hours)} \tag{3.5}$$

Tables showing the section wise calculations of Travel Time Savings on route from Faisalabad to Lahore through Sheikupura on dual carriage way are given in appendix E. From

these calculations, we get a total of 33 minutes saved approximately on the whole road section with 3 minutes, 8 minutes, 5.5 minutes, 9 minutes and 7.5 minutes saved on section 1 to section 5 respectively. Tables representing the money saved by saving the above mentioned time are also given in appendix E. The total travel time savings come out to be 25757.51 Million PKR (2007 Constant Rupees).

3.7 Safety Savings

Transportation projects generally have a safety component which directly or indirectly reduces the rate or severity of accidents. As such, enhancing safety is a key aspect of the user associated benefits of physical or policy changes in the transportation system. The economic cost of transport accidents are borne by individuals, insurance companies, government, and consist of a loss of productivity, and the destruction of property, loss of domestic production costs and workplaces.

The cost of accidents can be very high. In the development of the highway, safety problems are more subtle in roads especially in rural areas and on roads that have only one lane in each direction. Most of these roads are designed and built several decades ago using standards that are now outdated. As such, it is usually characterized by a lack of the operating and safety arising from inadequate road engineering, driver characteristics and lack of information, lack of passing opportunities, and conflicts because of the traffic entrances. Transportation interventions are made to raise the level of these facilities to acceptable standards.

Given below are the procedures, formulas, graphs and tables that are to be used for the calculation of accidents, reduction in number of crashes due to introduction of an intervention and savings monetary value.

First of all, Annual VMT (Vehicles miles travelled) is found using the formula;

$$\text{Annual VMT} = \text{AADT} * \text{Length (miles)} * 365 \quad (3.6)$$

To convert these vehicle miles to 100 Million Miles;

$$\text{Annual VMT (100 M)} = \frac{\text{AADT} * \text{Length(miles)} * 365}{10^8} \quad (3.7)$$

As the Crashes data is given for the after intervention case, so we can find the fatal and non-fatal crash rate for every 100 Million miles travelled using the following formulas;

$$\text{Fatal Crash Rate} = \frac{\text{No.of Fatal Crashes}}{\text{VMT (100M)}} \quad (3.8)$$

$$\text{Non} - \text{Fatal Crash Rate} = \frac{\text{No.of Non}-\text{Fatal Crashes}}{\text{VMT (100M)}} \quad (3.9)$$

Using these formulas, fatal and non-fatal crash rate was found for first eight years and then this is averaged to find the fatal and non-fatal crash rate for the life time. Fatal and Non-fatal crash rate for the before intervention is find using the average of rates plus 17% increase unpaved shoulder and 23% increase because of lesser number of lanes using the table given in appendix G.

Road crashes cost greatly depends upon the gross domestic product. In 2007, Per Capita income of Pakistan was $1085. Fatality Crash Cost is considered to be 70 times the GDP of country and injury cost is 18 times GDP (Smith and Barss, 1991). So, Fatal Crash Cost is considered to be $75950 and Non-Fatal Crash Cost is considered to be $19530.

Once the number of crashes and their cost is known, total cost can be found using the following formulas,

$$\text{Fatal Crash Cost} = \text{No. of Fatal crashes} * \text{Cost of unit Fatal Crash Cost} \quad (3.10)$$

$$\text{Non} - \text{Fatal Crash Cost} = \text{No. of Non} - \text{Fatal Crashes} * \text{Cost of Unit Non} - \text{Fatal Crash Cost} \quad (3.11)$$

$$\text{Total Crash Cost} = \text{Cost for fatal crashes} + \text{cost for non} - \text{fatal crashes} \quad (3.12)$$

After find the costs of crashes for before and after implementation, safety savings are find using;

$$\text{Safety Savings} = \text{Cost of crashes before intervention} - \text{cost of crashes after intervention} \quad (3.13)$$

Work sheets showing the calculations of fatal and non-fatal crashes for the two section i-e.; Faisalabad to Sheikhupura and Sheikhupura to Lahore, costs associated with these crashes and how they contribute towards the economic value of the intervention are given in appendix G.

Appendix G also includes tables representing the safety cost savings for both the sections of the road.

From the calculations in Table (appendix G), it is noticeable that number of accidents is increasing on Sheikhupura to Lahore section tremendously resulting in an increase in crash cost. This increase in crashes and their associated costs can be attributed to increase in AADT. With increase in average daily traffic, associated VMT are also increased which results in increase in fatal and non-fatal crash rate.

3.8 Vehicle Operating Costs Savings

Major factors that contribute towards the vehicle operating costs are consumption of fuel and oil, tire wear and tear, and vehicle maintenance and repair.

VOC Models and Look-up Table Based on Speed and Vehicle Class Hepburn (1994) developed a VOC model for urban roadways that considers the sum of four VOC components i.e.; tires, vehicle depreciation, vehicle maintenance, and fuel consumption as a function of two VOC factors; speed and vehicle class. The Hepburn function is as follows;

For low speeds;

Speeds (<50mph); $VOC = C + \frac{D}{S}$ (3.14)

For high speeds;

Speeds (>50mph); $VOC = a_o - a_1 S + a_2 S^2$ (3.15)

Using the model, calculations on the subject project are made and VOC savings come out to be 343.6 Billion (2007) PKR which seems to be quiet unrealistic so calculations considering only the fuel costs are done. Fuel costs greatly depend on the delay due to nodes and links. Delay causes an increase in vehicle operating costs, user inconvenience and frustration. The impacts of travel delay on fuel cost can be estimated using AASHTO (2003) methodology. The delay time with and without the intervention is find and change in the delay is find as;

$$\text{Change in delay} = \text{Delay without intervention} - \text{Delay with intervention} \quad (3.16)$$

The change in delay is considered to be one minute on each section of the road as road is improved. After finding the change in delay and free flow speeds known, Fuel Consumption in Gallons per Minute of Delay by Vehicle Type is found using the table given below;

Table 3.2 Fuel Consumption (Gallons*) per Minute of Delay by Vehicle Type

Free Flow Speed	Small Automobile	Large Automobile	SUV	2-Axle Single Unit Truck	3-Axle Single Unit Truck	Multiple Unit Truck
20	0.011	0.022	0.023	0.074	0.102	0.198
25	0013	0.026	0.027	0.097	0.133	0.242
30	0.015	0.030	0.032	0.122	0.167	0.284
35	0.018	0.034	0.037	0.149	0.203	0.327
40	0.021	0.038	0.043	0.177	0.241	0.369
45	0.025	0.043	0.049	0.206	0.281	0.411
50	0.028	0048	0.057	0.235	0.321	0.453
55	0.032	0.054	0.065	0.266	0.362	0.495
60	0.037	0.060	0.073	0.297	0.404	0.537
65	0.042	0.066	0.083	0.328	0.447	0.578
70	0.047	0.073	0.094	0.360	0.490	0.620
75	0.053	0.080	0.105	0.392	0.534	0.661

**One US gallon= 3.785 Liters*

And the cost of delay is found as;

$$\text{Total Cost of Delay} = \text{Change in Delay} * \text{Fuel Consumption rates} * \text{Unit Price of Fuel} \quad (3.17)$$

From the fuel consumption saving, fuel cost is found as;

$$\text{Fuel Cost Saving} = \text{Fuel Consumption } \left(\frac{\text{Gallons}}{\text{Minute}}\right) * \text{Saving in delay} * 3.785 * 365 * \text{cost of fuel (unit)} \quad (3.18)$$

The price of unit liter of fuel is taken to be 58 PKR in base year .i. e.; 2007. (Pakistan Bureau of Statistics)

Appendix H is representing the work sheets showing the calculations of fuel costs savings on the five section of the road from Faisalabad-Sheikhupura-Lahore.

3.9 Toll Collection

Toll rates are given for the period of first eight years of the service of the road .i. e.; 2007-2014. Notification issued on 31st August, 2006 shows that toll will be increased at the rate of 5.74% per annum. The table given below shows the toll rates as per Government of Pakistan Schedule for different types of the vehicles using the dual carriageway. Major vehicles are cares, jeeps, wagons, buses, mini trucks, 2-axle trucks, multi axle trucks and trucks with trolleys carrying different agricultural and industrial goods. Toll is also applicable on rickshaws only if they are having more than 2 passengers. Toll collection of rickshaws is not included in the calculation of monetary benefits earned.

Table 3.3 Toll Rates as per GOPs

TOLL RATES AS PER GOPb NOTIFICATION # SOHII(C&W)/4-1/2002-03(PSPIC)-VOL-II DATED 31 AUGUST 2006 INCREASE @ 5.74% PER ANNUM ON LAHORE-SHEIKHUPURA-FAISALABAD DUAL CARRIAGEWAY (BOT) PROJECT FROM BASE YEAR (i.e FIN YEAR 2001-2002 TO 2027-2028)													
	2001-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14
Car, Jeep, Taxi	60.00	63.44	67.09	70.94	75.01	79.31	83.87	88.68	93.77	99.15	104.84	110.86	**117.23**
Wagon, Pickup	109.00	115.26	121.87	128.87	136.26	144.09	152.36	161.10	170.35	180.13	190.47	201.40	**212.96**
Bus Upto 30 Seats	**151.66**	**160.37**	**169.57**	**179.30**	**189.60**	**200.48**	**211.99**	**224.15**	**237.02**	**250.63**	**265.01**	**280.22**	**296.31**
Bus	166.00	175.53	185.60	196.26	207.52	219.43	232.03	245.35	259.43	274.32	290.07	306.72	**324.32**
Mini Truck	190.00	200.91	212.44	224.63	237.53	251.16	265.58	280.82	296.94	313.98	332.01	351.06	**371.21**
Truck 2 Axle	219.00	231.57	244.86	258.92	273.78	289.49	306.11	323.68	342.26	361.91	382.68	404.65	**427.87**
Truck 3 Axle	219.00	231.57	244.86	258.92	273.78	289.49	306.11	323.68	342.26	361.91	382.68	404.65	**427.87**
Multi Axle Truck / Trailers	333.00	352.11	372.33	393.70	416.30	440.19	465.46	492.17	520.43	550.30	581.89	615.29	**650.60**
Tractor Trolley with Agriculture Goods	57.00	60.27	63.73	67.39	71.26	75.35	79.67	84.25	89.08	94.20	99.60	105.32	**111.36**
Tractor Trolley with Container / Industrial Goods	190.00	200.91	212.44	224.63	237.53	251.16	265.58	280.82	296.94	313.98	332.01	351.06	**371.21**
Rickshaw (More than 2 persons)	1.00	1.06	1.12	1.18	1.25	1.32	1.40	1.48	1.56	1.65	1.75	1.85	**1.95**

From the rates listed above, following tables show the benefits earned in the form of toll from the intervention;

Table 3.4 Toll Rates Collection as per GOPs

SR #	Year	Total Toll Collection on Sections (2007 PV)					Total Toll Collection
		Section 1	Section 2	Section 3	Section 4	Section 5	2007 PV
1	2007	573,003	318,499	175,937,419	231,645	284,125	177,344,690
2	2008	626,928	363,222	239,907,422	287,218	339,273	241,524,064
3	2009	624,528	323,308	261,028,974	283,643	340,032	262,600,486
4	2010	690,177	385,070	302,083,736	308,439	324,464	303,791,887
5	2011	686,371	417,169	322,970,341	326,523	354,963	324,755,367
6	2012	698,238	437,357	340,455,649	366,766	397,293	342,355,303
7	2013	695,074	432,963	312,053,698	375,857	389,356	313,946,948
8	2014	668,036	418,573	293,454,740	369,855	405,711	295,316,915
9	2015	706,382	442,599	305,192,929	391,085	428,999	307,161,993
10	2016	746,928	468,004	317,400,647	413,533	453,623	319,482,735
11	2017	789,801	494,868	330,096,673	437,270	479,661	332,298,273
12	2018	835,136	523,273	343,300,539	462,369	507,194	345,628,511
13	2019	883,073	553,309	357,032,561	488,909	536,307	359,494,158
14	2020	933,761	585,069	371,313,863	516,972	567,091	373,916,757
15	2021	987,359	618,652	386,166,418	546,646	599,642	388,918,717
16	2022	1,044,034	654,162	401,613,075	578,024	634,061	404,523,356
17	2023	1,103,961	691,711	417,677,598	611,202	670,456	420,754,929
18	2024	1,167,329	731,416	434,384,702	646,285	708,941	437,638,672
19	2025	1,234,333	773,399	451,760,090	683,382	749,634	455,200,838
20	2026	1,305,184	817,792	469,830,493	722,608	792,663	473,468,740
21	2027	1,380,101	864,733	488,623,713	764,086	838,162	492,470,795
22	2028	1,459,319	914,369	508,168,662	807,945	886,272	512,236,566
Total Toll Collection							**7,884,830,699**

3.10 Economy Efficiency Analysis

Due to transportation related problems like congestion, safety, efficiency, economy etc. there are usually many alternative decisions and actions, and each has a unique set of costs and benefits. The combined effect of monetary cost and benefit of each alternative can be represented, known as economic efficiency, performance measurement, which is derived using the principles of economic analysis. Economic analysis is a decision-making tool that assesses the efficiency of investment from the standpoint of cash and includes the costs and benefits associated with alternative monetary decisions and actions. There are several criteria available for the economic efficiency analysis;

- Present Worth of Costs (PWC)

- Equivalent Uniform Annual Cost (EUAC)
- Equivalent Uniform Annual Return (EUAR)
- Net Present Value (NPV)
- Internal Rate of Return (IRR)
- Benefit – Cost Ratio (BCR)

A net Present Value (NPV) criterion is used for the calculation of benefits and economic efficiency analysis in this study.

The monetary effect of construction of new road was analyzed using the following criteria:

- Life cycle of 22 years as per the concession period is considered
- Life cycle costs (construction cost as per LAFCO document and rehabilitation costs as per LAFCO and NHA schedules and operating and maintenance cost .i.e.; 15% of the toll income are considered) and Benefits (Travel Time Savings, Safety Savings, Fuel Savings and Toll Collection) are considered.
- Annual Growth rate of 4% for AADT is taken considered.
- Comparison of Net Present Values of both the benefits and costs are considered to assess the economic viability.

Following table represents the summary of benefits earned over the life of the concession period.

Table 3.5 Life Time Savings

Sr #	Year	TTS	Fuel Saving	Toll Collection	Safety Savings	Total 2007 PV
1	2007	1275.477	173.033101	177.34469	165.4128	1791.26785
2	2008	1338.12	191.348164	241.524064	-421.058	1349.93451
3	2009	1313.73	185.450393	262.600486	-94.3206	1667.46034
4	2010	1281.701	193.806785	303.791887	-105.104	1674.19563
5	2011	1296.757	197.44109	324.755367	-4.1764	1814.77659
6	2012	1343.598	198.370606	342.355303	169.008	2053.33179
7	2013	1234.462	181.569903	313.946948	-132.255	1597.72323
8	2014	1119.942	166.865127	295.316915	120.1161	1702.23981
9	2015	1118.904	166.865127	307.161993	23.63073	1616.56229
10	2016	1118.295	166.865127	319.482735	13.15791	1617.80076
11	2017	1126.242	166.865127	332.298273	13.15791	1638.56336
12	2018	1114.152	247.00115	345.628511	13.15791	1719.93989
13	2019	1112.556	166.865127	359.494158	13.15791	1652.07289
14	2020	1111.338	166.865127	373.916757	13.15791	1665.27769
15	2021	1110.488	166.865127	388.918717	13.15791	1679.43002
16	2022	1104.413	166.865127	404.523356	13.15791	1688.95943
17	2023	1109.318	166.865127	420.754929	13.15791	1710.09642
18	2024	1107.949	166.865127	437.638672	13.15791	1725.61077
19	2025	1107.108	166.865127	455.200838	13.15791	1742.33183
20	2026	1106.381	166.865127	473.46874	13.15791	1759.87242
21	2027	1104.583	166.865127	492.470795	13.15791	1777.077
22	2028	1101.997	166.865127	512.236566	13.15791	1794.25702
Total		**25757.5**	**3904.133**	**7884.8307**	**-107.69**	**37438.782**

Operation and maintenance and rehabilitation costs are given as below;

1. The table given below represents the Maintenance Schedule as described by the LAFCO. Operation and maintenance costs are taken as 15% of the toll income and rehabilitation costs schedule is given by the LAFCO.

Table 3.6 Maintenance Schedule by LAFCO

Sr #	Year	Costs of Rehab	Costs of Rehab	O &M costs	Total Cost
		Million PKR	2007 PKR	Million PKR	Million 2007 PKR
1	2006	5870	6104.8		6104.8
2	2007	2.2	2.2	26.60	28.88
3	2008	2.2	2.11	36.22	38.34
4	2009	2.2	2.03	39.39	41.42
5	2010	2.2	1.95	45.56	47.52
6	2011	2.2	1.88	48.71	50.59
7	2012	2.2	1.80	51.35	53.16
8	2013	2.2	1.73	47.09	48.83
9	2014	3800	2887.68	44.29	2931.97
10	2015	2.2	1.60	46.07	47.68
11	2016	2.2	1.54	47.92	49.46
12	2017	2.2	1.48	49.84	51.3
13	2018	2.2	1.42	51.84	53.27
14	2019	2.2	1.37	53.92	55.29
15	2020	2.2	1.32	56.08	57.40
16	2021	6000	3464.85	58.33	3523.18
17	2022	2.2	1.22	60.67	61.90
18	2023	2.2	1.17	63.11	64.28
19	2024	2.2	1.12	65.64	66.77
20	2025	2.2	1.08	68.28	69.36
21	2026	2.2	1.04	71.02	72.06
22	2027	2.2	1.00	73.87	74.87
23	2028	2.2	0.96	76.83	77.80
		Total Life Cycle Costs			**13670.18**

From the table it is clear that first structural overlay was scheduled to the road network in 2014 which costs 3.8 billion and second overlay will be provided in 2021 which will cost 6 billion. Following figure shows the graphical view of schedule of rehabilitation as described by LAFCO.

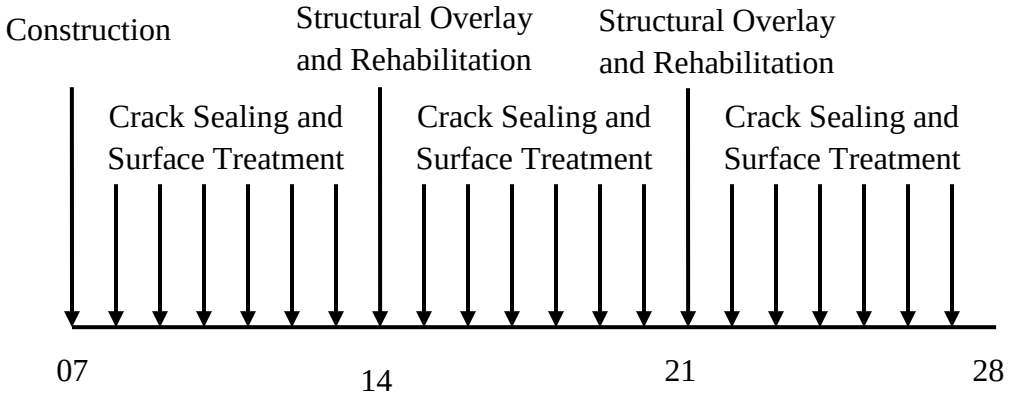

Figure 3. 3 Maintenance and Rehabilitation Profile by LAFCO

To generate more benefits and to reduce the cost of maintenance and rehabilitation during the life course of the roadway, a rehabilitation and maintenance schedule is developed and is as shown below;

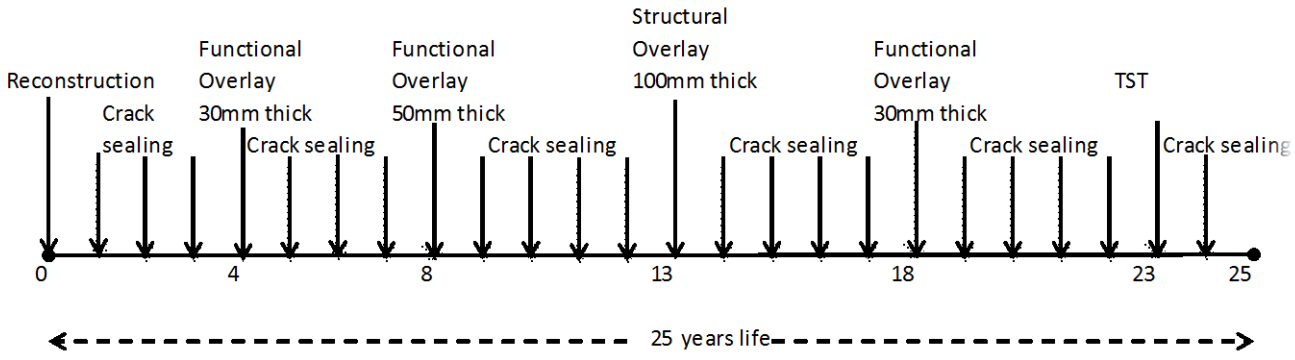

Figure 3.4 Profile of Maintenance and Rehabilitation developed

According to this schedule, if functional overlays are given after short intervals, a major structural overlay will be need after serving for a longer time period and these functional overlays will cost less so total maintenance and rehabilitation costs for the life course of the asset can be reduced and hence benefits will be enhanced.

Table 3.7 shows the summary of maintenance and rehabilitation cost summary according to the schedule of maintenance and rehabilitation shown in figure 3.4.

Table 3.7 Maintenance Schedule Proposed

Sr #	Year	Costs of Rehab	Costs of Rehab	O &M costs	Total Cost
		Million PKR	2007 PKR	Million PKR	Million 2007 PKR
1	2006	5870	6104.8		6104.8
2	2007	2.2	2.2	26.60170348	28.80170348
3	2008	2.2	2.115384615	36.2286096	38.34399422
4	2009	2.2	2.034023669	39.39007288	41.42409655
5	2010	2.2	1.955791989	45.56878301	47.524575
6	2011	2.2	1.88056922	48.71330501	50.59387423
7	2012	2.2	1.808239635	51.35329543	53.16153506
8	2013	6.37	2315.78	47.09204217	2362.872042
9	2014	2.2	1.671819189	44.29753724	45.96935643
10	2015	2.2	1.607518451	46.074299	47.68181745
11	2016	2.2	1.545690818	47.92241022	49.46810104
12	2017	2.2	1.486241171	49.84474088	51.33098205
13	2018	2.2	1.429078049	51.84427669	53.27335474
14	2019	10.82	3108.744	53.92412376	3162.668124
15	2020	2.2	1.321262989	56.08751348	57.40877647
16	2021	2.2	1.270445182	58.33780757	59.60825276
17	2022	2.2	1.221581906	60.67850338	61.90008528
18	2023	2.2	1.174597987	63.11323935	64.28783733
19	2024	2.2	1.129421141	65.64580076	66.7752219
20	2025	2.2	1.085981866	68.28012565	69.36610751
21	2026	6.37	1390.797	71.02031103	1461.817311
22	2027	2.2	1.004051282	73.87061929	74.87467057
23	2028	2.2	0.965433925	76.83548495	77.80091887
Total Life Cycle Costs				**14131.75274**	

Using the costs of operation & Maintenance and rehabilitation as described by LAFCO schedule and the benefits i. e.; Travel Time Savings, Safety Savings, Fuel Cost Savings and Toll Collection Savings, benefits comes out to be as shown below;

Table 3.8 Economic Benefit Analysis

Sr #	Year	TTS	Fuel Saving	Toll	Safety	Total	Costs of O & M and Rehab
						2007 PV	Million 2007 PKR
1	2006						6104.8
2	2007	1275.47	173.03	177.34	165.41	1791.26	28.80
3	2008	1338.12	191.34	241.52	-421.05	1349.93	38.34
4	2009	1313.73	185.45	262.60	-94.32	1667.4	41.42
5	2010	1281.70	193.80	303.79	-105.10	1674.19	47.52
6	2011	1296.75	197.44	324.75	-4.17	1814.77	50.59
7	2012	1343.59	198.37	342.35	169.00	2053.33	53.16
8	2013	1234.46	181.56	313.94	-132.25	1597.72	48.83
9	2014	1119.94	166.86	295.31	120.11	1702.24	2931.98
10	2015	1118.90	166.86	307.16	23.63	1616.56	47.68
11	2016	1118.29	166.86	319.48	13.15	1617.80	49.46
12	2017	1126.24	166.86	332.29	13.15	1638.53	51.33
13	2018	1114.15	247.00	345.62	13.15	1719.9	53.27
14	2019	1112.55	166.86	359.49	13.15	1652.07	55.29
15	2020	1111.33	166.86	373.91	13.15	1665.27	57.40
16	2021	1110.48	166.86	388.91	13.15	1679.4	3523.18
17	2022	1104.41	166.86	404.52	13.15	1688.95	61.90
18	2023	1109.31	166.86	420.75	13.15	1710.09	64.28
19	2024	1107.94	166.86	437.63	13.15	1725.61	66.77
20	2025	1107.10	166.86	455.20	13.15	1742.33	69.36
21	2026	1106.38	166.86	473.46	13.15	1759.87	72.06
22	2027	1104.58	166.86	492.47	13.15	1777.07	74.87
23	2028	1101.99	166.86	512.23	13.15	1794.25	77.80
			Total			**37438.78**	**13670.18468**

From the above table, benefits earned over the life time of the carriageway are 23768.59 Million PKR (2007 Constant Rupees).

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter comprises the detailed discussions on results of benefits. In the first portion of the chapter, summary of travel time savings, safety savings, fuel cost savings and toll collection savings are summarized. In the second portion of the chapter, the different schedules of maintenance and rehabilitation costs as considered. One schedule is proposed by LAFCO and the other one is developed to minimize the costs of rehabilitation and hence increase the benefits.

4.2 Travel Time Savings Summary

All these savings are in Million PKR (2007 Constant PKR)

Table 4.1 Travel Time Saving Summary

Sr #	Year	Section 1	Section 2	Section 3	Section 4	Section 5	Total
1	2007	221.78	228.99	209.25	306.63	308.83	1275.48
2	2008	211.52	239.99	224.63	323.34	338.65	1338.12
3	2009	203.23	216.19	227.81	335.72	330.78	1313.73
4	2010	197.82	220.18	236.53	340.94	286.23	1281.70
5	2011	190.01	213.08	243.19	350.37	300.11	1296.76
6	2012	176.42	209.46	248.92	379.17	329.63	1343.60
7	2013	159.20	194.71	231.08	354.04	295.43	1234.46
8	2014	144.41	187.07	209.67	306.98	271.81	1119.94
9	2015	144.17	186.88	209.75	306.56	271.55	1118.90
10	2016	143.99	186.98	209.59	306.41	271.33	1118.29
11	2017	143.57	187.18	209.27	315.20	271.02	1126.24
12	2018	143.57	185.10	209.38	305.35	270.76	1114.15
13	2019	143.55	184.52	208.97	305.02	270.49	1112.56
14	2020	143.57	184.39	209.00	304.59	269.78	1111.34
15	2021	143.55	184.35	208.89	304.44	269.26	1110.49
16	2022	143.51	178.79	208.79	304.33	269.00	1104.41
17	2023	143.32	184.46	208.72	304.08	268.74	1109.32
18	2024	142.88	184.50	208.61	303.55	268.41	1107.95
19	2025	142.73	184.57	208.54	303.31	267.95	1107.11
20	2026	142.68	184.61	208.48	302.99	267.63	1106.38
21	2027	142.44	184.68	208.41	302.66	266.39	1104.58
22	2028	141.82	184.05	208.26	302.20	265.67	1102.00
						Total	**25757.51**

From the above table of summary, it is known that travel time savings contributed 25.8 Billion PKR (2007 const.) in the total earnings from the road assets.

4.3 Safety Savings

All the safety savings for the concession period are summarized in the table given below as;

Table 4.2 Safety Savings Summary

Sr	Year	Cost before Intervention	Cost after Intervention	Savings Million PKR
1	2007	528.15	362.74	165.41
2	2008	528.15	949.21	-421.06
3	2009	528.15	622.47	-94.32
4	2010	528.15	633.25	-105.10
5	2011	528.15	532.33	-4.18
6	2012	528.15	359.14	169.01
7	2013	528.15	660.41	-132.26
8	2014	528.15	408.03	120.12
9	2015	528.15	504.52	23.63
10	2016	528.15	514.99	13.16
11	2017	528.15	514.99	13.16
12	2018	528.15	514.99	13.16
13	2019	528.15	514.99	13.16
14	2020	528.15	514.99	13.16
15	2021	528.15	514.99	13.16
16	2022	528.15	514.99	13.16
17	2023	528.15	514.99	13.16
18	2024	528.15	514.99	13.16
19	2025	528.15	514.99	13.16
20	2026	528.15	514.99	13.16
21	2027	528.15	514.99	13.16
22	2028	528.15	514.99	13.16
			Total	**-107.69**

These savings are calculated using the average of the fatal and non-fatal crash rates from the data given for the first eight years of service of intervention. Number of accidents increase as the average daily traffic increases and hence the cost associated with these increases.

4.4 Fuel Cost Savings

Fuel cost savings are the savings in the fuel cost to the users of new road network. New network reduces bumps and cracks and provides a path for the smooth flow of the traffic. Table 4.3 representing the savings in the fuel cost due to intervention;

Table 4.3 Fuel Cost Savings Summary

Sr #	Year	Section 1	Section 2	Section 3	Section 4	Section 5	Total Saving	Total Savings	Total Savings
							PKR	Million PKR	2007 PV
1	2007	61020860	32173055	25198274	22908804	31732108	173033100.9	173.0331009	173.0331
2	2008	66671478	36224590	29763152	27909180	38433691	199002090.5	199.0020905	191.3482
3	2009	67074724	33963485	31519848	29202413	38822675	200583145	200.583145	185.4504
4	2010	72942050	40288865	34671059	32279105	37825196	218006275.2	218.0062752	193.8068
5	2011	73767894	44777581	36294863	34363446	41774366	230978149.8	230.9781498	197.4411
6	2012	72714044	46346616	38210333	38459452	45617728	241348173.5	241.3481735	198.3706
7	2013	69638113	44766964	33720055	37801398	43817321	229743851.1	229.7438511	181.5699
8	2014	65200520	42788352	36665977	36655320	38272954	219583123	219.583123	166.8651
9	2015	67808541	44499886	38132617	38121533	39803872	228366447.9	228.3664479	166.8651
10	2016	70520882	46279881	39657921	39646394	41396027	237501105.8	237.5011058	166.8651
11	2017	73341717	48131077	41244238	41232250	43051868	247001150	247.00115	166.8651
12	2018	76275386	50056320	42894008	42881540	44773942	256881196	256.881196	166.8651
13	2019	79326402	52058573	44609768	44596802	46564900	267156443.9	267.1564439	166.8651
14	2020	82499458	54140915	46394159	46380674	48427496	277842701.6	277.8427016	166.8651
15	2021	85799436	56306552	48249925	48235901	50364596	288956409.7	288.9564097	166.8651
16	2022	89231413	58558814	50179922	50165337	52379180	300514666.1	300.5146661	166.8651
17	2023	92800670	60901167	52187119	52171950	54474347	312535252.7	312.5352527	166.8651
18	2024	96512697	63337213	54274604	54258828	56653321	325036662.8	325.0366628	166.8651
19	2025	1E+08	65870702	56445588	56429182	58919454	338038129.3	338.0381293	166.8651
20	2026	1.04E+08	68505530	58703411	58686349	61276232	351559654.5	351.5596545	166.8651
21	2027	1.09E+08	71245751	61051548	61033803	63727281	365622040.7	365.6220407	166.8651
22	2028	1.13E+08	74095581	63493610	63475155	66276372	380246922.3	380.2469223	166.8651
								Total Cost	**3824**

Overall savings associated to the fuel cost for the concession period comes out to be 3.8 Billion PKR (2007 constant rupees).

4.5 Toll Earnings

Toll Earning is the actual amount of money builder is making in the concession period. Table given below represents the toll collected on each section;

Table 4.4 Toll Earnings

Sr #	Year	Toll Collection Section wise(2007 PV)					Total Toll Collection
		Section 1	Section 2	Section 3	Section 4	Section 5	2007 PV
1	2007	573,003	318,499	175,937,419	231,645	284,125	177,344,690
2	2008	626,928	363,222	239,907,422	287,218	339,273	241,524,064
3	2009	624,528	323,308	261,028,974	283,643	340,032	262,600,486
4	2010	690,177	385,070	302,083,736	308,439	324,464	303,791,887
5	2011	686,371	417,169	322,970,341	326,523	354,963	324,755,367
6	2012	698,238	437,357	340,455,649	366,766	397,293	342,355,303
7	2013	695,074	432,963	312,053,698	375,857	389,356	313,946,948
8	2014	668,036	418,573	293,454,740	369,855	405,711	295,316,915
9	2015	706,382	442,599	305,192,929	391,085	428,999	307,161,993
10	2016	746,928	468,004	317,400,647	413,533	453,623	319,482,735
11	2017	789,801	494,868	330,096,673	437,270	479,661	332,298,273
12	2018	835,136	523,273	343,300,539	462,369	507,194	345,628,511
13	2019	883,073	553,309	357,032,561	488,909	536,307	359,494,158
14	2020	933,761	585,069	371,313,863	516,972	567,091	373,916,757
15	2021	987,359	618,652	386,166,418	546,646	599,642	388,918,717
16	2022	1,044,034	654,162	401,613,075	578,024	634,061	404,523,356
17	2023	1,103,961	691,711	417,677,598	611,202	670,456	420,754,929
18	2024	1,167,329	731,416	434,384,702	646,285	708,941	437,638,672
19	2025	1,234,333	773,399	451,760,090	683,382	749,634	455,200,838
20	2026	1,305,184	817,792	469,830,493	722,608	792,663	473,468,740
21	2027	1,380,101	864,733	488,623,713	764,086	838,162	492,470,795
22	2028	1,459,319	914,369	508,168,662	807,945	886,272	512,236,566
Total Toll Collection							**7,884,830,699**

Toll collection is the tangible monetary earning that is actually earned and a part of it is used in the operation and maintenance and rehabilitation of the intervention during the concession period.

For exploring more options for analyzing the benefits, four different options have been tried as listed below;

1. Option 1 (Travel Time Saving is included and the Maintenance Cost by LAFCO is considered)
2. Option 2 (Travel Time Saving is not included and the Maintenance Cost by LAFCO is considered)

3. Option 3 (Travel Time Saving is included and the Maintenance Cost as per realistic schedule is considered)
4. Option 4 (Travel Time Saving is not included and the Maintenance Cost as per realistic schedule is considered)

Given below are the tables representing the benefits and the costs for the four options considered for analysis;

Table 4.5 Option 1 (Travel Time Saving is included and the Maintenance Cost by LAFCO is considered)

Sr #	Year	TTS	Fuel Saving	Toll	Safety	Total	Costs of O & M and Rehab
						2007 PV	Million 2007 PKR
1	2006						6104.8
2	2007	1275.477	173.0331	177.3447	165.4128	1791.268	28.80170348
3	2008	1338.12	191.3482	241.5241	-421.058	1349.935	38.34399422
4	2009	1313.73	185.4504	262.6005	-94.3206	1667.46	41.42409655
5	2010	1281.701	193.8068	303.7919	-105.104	1674.196	47.524575
6	2011	1296.757	197.4411	324.7554	-4.1764	1814.777	50.59387423
7	2012	1343.598	198.3706	342.3553	169.008	2053.332	53.16153506
8	2013	1234.462	181.5699	313.9469	-132.255	1597.723	48.83073413
9	2014	1119.942	166.8651	295.3169	120.1161	1702.24	2931.985227
10	2015	1118.904	166.8651	307.162	23.63073	1616.562	47.68181745
11	2016	1118.295	166.8651	319.4827	13.15791	1617.801	49.46810104
12	2017	1126.242	166.8651	332.2983	13.15791	1638.563	51.33098205
13	2018	1114.152	247.0012	345.6285	13.15791	1719.94	53.27335474
14	2019	1112.556	166.8651	359.4942	13.15791	1652.073	55.29823727
15	2020	1111.338	166.8651	373.9168	13.15791	1665.278	57.40877647
16	2021	1110.488	166.8651	388.9187	13.15791	1679.43	3523.188305
17	2022	1104.413	166.8651	404.5234	13.15791	1688.959	61.90008528
18	2023	1109.318	166.8651	420.7549	13.15791	1710.096	64.28783733
19	2024	1107.949	166.8651	437.6387	13.15791	1725.611	66.7752219
20	2025	1107.108	166.8651	455.2008	13.15791	1742.332	69.36610751
21	2026	1106.381	166.8651	473.4687	13.15791	1759.872	72.06452436
22	2027	1104.583	166.8651	492.4708	13.15791	1777.077	74.87467057
23	2028	1101.997	166.8651	512.2366	13.15791	1794.257	77.80091887
Total						**37438.8**	**13670.18468**

Table 4.6 Option 2 (Travel Time Saving is not included and the Maintenance Cost by LAFCO is considered)

Sr #	Year	Fuel Saving	Toll	Safety	Total	Costs of Rehab
					2007 PV	Million PKR
1	2006					6104.8
2	2007	173.0331	177.3447	165.4128	515.7906	28.80170348
3	2008	191.3482	241.5241	-421.058	11.81415	38.34399422
4	2009	185.4504	262.6005	-94.3206	353.7303	41.42409655
5	2010	193.8068	303.7919	-105.104	392.4951	47.524575
6	2011	197.4411	324.7554	-4.1764	518.0201	50.59387423
7	2012	198.3706	342.3553	169.008	709.7339	53.16153506
8	2013	181.5699	313.9469	-132.255	363.2614	48.83073413
9	2014	166.8651	295.3169	120.1161	582.2981	2931.985227
10	2015	166.8651	307.162	23.63073	497.6578	47.68181745
11	2016	166.8651	319.4827	13.15791	499.5058	49.46810104
12	2017	166.8651	332.2983	13.15791	512.3213	51.33098205
13	2018	247.0012	345.6285	13.15791	605.7876	53.27335474
14	2019	166.8651	359.4942	13.15791	539.5172	55.29823727
15	2020	166.8651	373.9168	13.15791	553.9398	57.40877647
16	2021	166.8651	388.9187	13.15791	568.9418	3523.188305
17	2022	166.8651	404.5234	13.15791	584.5464	61.90008528
18	2023	166.8651	420.7549	13.15791	600.778	64.28783733
19	2024	166.8651	437.6387	13.15791	617.6617	66.7752219
20	2025	166.8651	455.2008	13.15791	635.2239	69.36610751
21	2026	166.8651	473.4687	13.15791	653.4918	72.06452436
22	2027	166.8651	492.4708	13.15791	672.4938	74.87467057
23	2028	166.8651	512.2366	13.15791	692.2596	77.80091887
		Total			**11681.3**	**13670.18468**

Table 4.7 Option 3. (Travel Time Saving is included and the Maintenance Cost as prescribed is considered)

Sr #	Year	TTS	Fuel Saving	Toll	Safety	Total	Costs of O & M and Rehab
						2007 PV	Million 2007 PKR
1	2006						6104.8
2	2007	1275.477	173.0331	177.3447	165.4128	1791.268	28.80170348
3	2008	1338.12	191.3482	241.5241	-421.058	1349.935	38.34399422
4	2009	1313.73	185.4504	262.6005	-94.3206	1667.46	41.42409655
5	2010	1281.701	193.8068	303.7919	-105.104	1674.196	47.524575
6	2011	1296.757	197.4411	324.7554	-4.1764	1814.777	50.59387423
7	2012	1343.598	198.3706	342.3553	169.008	2053.332	53.16153506
8	2013	1234.462	181.5699	313.9469	-132.255	1597.723	2362.872042
9	2014	1119.942	166.8651	295.3169	120.1161	1702.24	45.96935643
10	2015	1118.904	166.8651	307.162	23.63073	1616.562	47.68181745
11	2016	1118.295	166.8651	319.4827	13.15791	1617.801	49.46810104
12	2017	1126.242	166.8651	332.2983	13.15791	1638.563	51.33098205
13	2018	1114.152	247.0012	345.6285	13.15791	1719.94	53.27335474
14	2019	1112.556	166.8651	359.4942	13.15791	1652.073	3162.668124
15	2020	1111.338	166.8651	373.9168	13.15791	1665.278	57.40877647
16	2021	1110.488	166.8651	388.9187	13.15791	1679.43	59.60825276
17	2022	1104.413	166.8651	404.5234	13.15791	1688.959	61.90008528
18	2023	1109.318	166.8651	420.7549	13.15791	1710.096	64.28783733
19	2024	1107.949	166.8651	437.6387	13.15791	1725.611	66.7752219
20	2025	1107.108	166.8651	455.2008	13.15791	1742.332	69.36610751
21	2026	1106.381	166.8651	473.4687	13.15791	1759.872	1461.817311
22	2027	1104.583	166.8651	492.4708	13.15791	1777.077	74.87467057
23	2028	1101.997	166.8651	512.2366	13.15791	1794.257	77.80091887
Total						**37438.8**	**14131.75274**

Table 4.8 Option 4 (Travel Time Saving is not included and the Maintenance Cost as prescribed is considered)

Sr #	Year	Fuel Saving	Toll	Safety	Total	Costs of O & M and Rehab
					2007 PV	Million 2007 PKR
1	2006					6104.8
2	2007	173.0331	177.3447	165.4128	515.7906	28.80170348
3	2008	191.3482	241.5241	-421.058	11.81415	38.34399422
4	2009	185.4504	262.6005	-94.3206	353.7303	41.42409655
5	2010	193.8068	303.7919	-105.104	392.4951	47.524575
6	2011	197.4411	324.7554	-4.1764	518.0201	50.59387423
7	2012	198.3706	342.3553	169.008	709.7339	53.16153506
8	2013	181.5699	313.9469	-132.255	363.2614	2362.872042
9	2014	166.8651	295.3169	120.1161	582.2981	45.96935643
10	2015	166.8651	307.162	23.63073	497.6578	47.68181745
11	2016	166.8651	319.4827	13.15791	499.5058	49.46810104
12	2017	166.8651	332.2983	13.15791	512.3213	51.33098205
13	2018	247.0012	345.6285	13.15791	605.7876	53.27335474
14	2019	166.8651	359.4942	13.15791	539.5172	3162.668124
15	2020	166.8651	373.9168	13.15791	553.9398	57.40877647
16	2021	166.8651	388.9187	13.15791	568.9418	59.60825276
17	2022	166.8651	404.5234	13.15791	584.5464	61.90008528
18	2023	166.8651	420.7549	13.15791	600.778	64.28783733
19	2024	166.8651	437.6387	13.15791	617.6617	66.7752219
20	2025	166.8651	455.2008	13.15791	635.2239	69.36610751
21	2026	166.8651	473.4687	13.15791	653.4918	1461.817311
22	2027	166.8651	492.4708	13.15791	672.4938	74.87467057
23	2028	166.8651	512.2366	13.15791	692.2596	77.80091887
		Total			**11681.3**	**14131.75274**

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 General

The core of transportation decision making is the evaluation of transportation projects and programs in the context of available funding as it involves taxpayer's money. For this reason, the principles and procedures of transportation project evaluation and programming are of interest to transportation engineers and planners, transportation agency administrators, facility managers and service providers, environmental groups and the general public. This is a critical issue for governments everywhere. Each year, several trillions of dollars are invested worldwide in transportation facilities with a view to enhancing transportation system mobility, security, and safety, and to spurring economic development while minimizing environmental and other adverse impacts. Same is the case within Pakistan.

Pakistan is a developing country. Road infrastructure is the main mean of transportation. Lahore and Faisalabad are the two main industrial cities of Pakistan. Lahore is the country's second largest economic hub and the commercial capital of Punjab. In 2008, the city was ranked with high efficiency to be classified as a gamma world city. Faisalabad has a predominantly agriculture and industry-based economy and forms a backbone of Pakistan's textiles production sector, with a population exceeding 2 million; it is the country's third largest city. Lahore-Sheikhupura-Faisalabad dual carriageway is the linking road network connecting the two major cities.

The motive of the research was intended to review the indications of good practices with respect to the case study of Lahore-Sheikhupura-Faisalabad dual carriageway that could be followed in the evaluation of alternatives transportation systems for the purpose of decision making, on the ground of demand estimation and Traffic on different segments, travel time savings and analysis that proved to be the cost of 25.757 Billion PKR, the safety costs (loss) were around 107.694 Million PKR, the vehicle operating saving cost proved to be 3.904 Billion 2007 constant PKR, Also, net present value of toll collection is of Rs. 7.9 Billion (2007 constant rupees).

5.2 Conclusions and Recommendations

Lahore-Sheikhupura-Faisalabad dual carriage way has overall benefitted the society. The dual carriage way has surely reduced congestion and hence improving the speed thus enhancing the travel time savings. It also has benefitted the users as vehicle operating costs have reduced. Saving travel time and its analysis showed the cost of 25.757 Billion PKR will be saved in the concession period of the national asset and proved that 80% of the quantified benefits are earned by reducing the travel times and enhancing the travel speeds. Lahore-Sheikhupura-Faisalabad dual carriage way's saving fuel cost is estimated to be 3.904 Billion in accordance to 2007 constant PKR. The estimated Safety Costs are around 107.7 Million PKR in this study. This study provides indications of good practices that could be followed in the evaluation of alternatives transportation systems for the purpose of decision making.

Pakistan is the developing country and user-friendly, fast and efficient road network is crucial for its sustained growth. This research study has demonstrated some of the salient features of the framework that can be used for performing the post implementation analysis of the road networks, and defines procedures to measure the benefits of new constructions. Post implementation evaluation studies of major construction project should be done to highlights their cost and benefits to society. All data pertaining to cost and traffic of BOT be shared with different stake holders for better transparency and education. Data collection must be paid serious attention for better results and must be shared for research work.

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APPENDICES

APPENDIX A. Average Traffic Count Category Per Day - Fy 2006-07 To 2013-14

Sr #	CATEGORY	FY 06- 07	FY 07-08	FY 08-09	FY 09-10	FY 10-11	FY 11-12	FY 12-13	FY 13-14
1	Cars / Jeep & Taxi	31925	38332	40181	43755	46505	48200	46881	46902
2	Wagon	8123	8076	8158	10141	12497	13538	12064	9729
3	Bus upto 30 Seats	1573	1710	1792	1170	1112	1173	1083	1103
4	Bus	4220	4356	4264	3882	3467	3467	3508	3732
5	Mini Truck	2696	3550	3541	3864	4052	4501	4697	4862
6	Truck 2 / 3 Axle	6944	7811	6450	6931	6059	5998	6212	5953
7	Trolley Agri Goods	881	900	795	829	726	809	813	830
8	Tractor With Container	207	220	190	216	173	174	160	145
9	Multi Axle Trailer	1250	1466	1242	1318	1396	1519	1614	1609
10	Rickshaw	3676	3024	3616	4140	2384	1382	300	524
	Total	61495	69445	70229	76245	78372	80762	77333	75388
	G. Total (Less Rickshaw)	57819	66421	66612	72106	75988	79379	77033	74864

APPENDIX B. Toll Plaza Wise TFC Count Per Day

Table B.1 Toll Plaza Wise TFC Count for FY 06-08

Sr #	CATEGORY	FY 06- 07						FY 07- 08					
		TP-1	TP-2	TP-3	TP-4	TP-5	Total	TP-1	TP-2	TP-3	TP-4	TP-5	Total
1	Cars / Jeep & Taxi	10699	5665	4927	4251	6383	31925	12172	6860	5902	5338	8060	38332
2	Wagon	3805	1538	631	842	1306	8123	3868	1187	742	856	1423	8076
3	Bus upto 30 Seats	705	193	148	216	311	1573	676	230	174	257	373	1710
4	Bus	907	851	787	749	926	4220	813	902	821	788	1031	4356
5	Mini Truck	1013	445	370	329	540	2696	1201	656	511	482	700	3550
6	Truck 2 / 3 Axle	2378	1600	1230	1009	727	6944	2549	1782	1414	1272	795	7811
7	Trolley Agri Goods	422	271	101	33	53	881	433	263	112	41	51	900
8	Tractor With Container	72	21	20	21	74	207	87	22	24	25	62	220
9	Multi Axle Trailer	307	217	266	249	209	1250	346	275	298	324	222	1466
10	Rickshaw	3652	23	0	0	0	3676	2989	0	0	0	35	3024
	Total	23961	10826	8479	7700	10529	61495	25136	12177	9998	9383	12751	69445
	G. Total (Less Rickshaw)	20308	10803	8479	7700	10529	57819	22147	12177	9998	9383	12716	66421

Table B.2 Toll Plaza Wise TFC Count for FY 08-10

S#	CATEGORY	FY 08- 09						FY 09- 10					
		TP-1	TP-2	TP-3	TP-4	TP-5	Total	TP-1	TP-2	TP-3	TP-4	TP-5	Total
1	Cars / Jeep & Taxi	12647	7023	6504	5792	8216	40181	13810	8099	7153	6428	8264	43755
2	Wagon	3838	851	853	1078	1538	8158	4277	1539	1235	1498	1592	10141
3	Bus upto 30 Seats	627	258	223	295	389	1792	454	185	154	169	208	1170
4	Bus	855	822	805	780	1002	4264	737	829	760	715	842	3882
5	Mini Truck	1208	580	542	497	715	3541	1351	699	632	575	608	3864
6	Truck 2 / 3 Axle	2220	1337	1223	997	673	6450	2546	1554	1201	1004	626	6931
7	Trolley Agri Goods	371	235	114	38	36	795	409	243	116	33	29	829
8	Tractor With Container	89	19	20	18	44	190	116	22	23	20	34	216
9	Multi Axle Trailer	352	220	235	241	194	1242	415	226	233	246	199	1318
10	Rickshaw	3582	0	0	0	34	3616	4139	0	0	0	0	4140
	Total	25788	11346	10519	9734	12842	70229	28253	13395	11507	10688	12402	76245
	G. Total (Less Rickshaw)	22206	11346	10519	9734	12807	66612	28253	13395	11507	10688	12402	72106

Table B.3 Toll Plaza Wise TFC Count for FY 10-12

S #	CATEGORY	FY 10-11						FY 11-12					
		TP-1	TP-2	TP-3	TP-4	TP-5	Total	TP-1	TP-2	TP-3	TP-4	TP-5	Total
1	Cars / Jeep & Taxi	14272	8922	7440	6830	9042	46505	13810	8099	7153	6428	8264	43755
2	Wagon	4577	2358	1568	1836	2158	12497	4277	1539	1235	1498	1592	10141
3	Bus upto 30 Seats	348	206	167	174	218	1112	454	185	154	169	208	1170
4	Bus	670	718	701	661	717	3467	737	829	760	715	842	3882
5	Mini Truck	1379	755	655	596	668	4052	1351	699	632	575	608	3864
6	Truck 2 / 3 Axle	2166	1367	1075	898	553	6059	2546	1554	1201	1004	626	6931
7	Trolley Agri Goods	358	193	114	32	30	726	409	243	116	33	29	829
8	Tractor With Container	84	18	21	18	33	173	116	22	23	20	34	216
9	Multi Axle Trailer	413	230	257	284	212	1396	415	226	233	246	199	1318
10	Rickshaw	2384	0	0	0	0	2384	4139	0	0	0	0	4140
	Total	26651	14765	11997	11329	13629	78372	25364	15282	12599	12649	14869	80762
	G. Total (Less Rickshaw)	24267	14765	11997	11329	13629	75988	23981	15282	12599	12649	14869	80762

Table B.4 Toll Plaza Wise TFC Count for FY 12-14

S #	CATEGORY	FY 12-13						FY 13-14					
		TP-1	TP-2	TP-3	TP-4	TP-5	Total	TP-1	TP-2	TP-3	TP-4	TP-5	Total
1	Cars / Jeep & Taxi	13417	9064	7720	7363	9317	46881	12593	8998	7677	7501	10134	46902
2	Wagon	3831	2081	1650	2172	2331	12064	3392	1498	1338	1625	1876	9729
3	Bus upto 30 Seats	304	209	176	194	198	1083	260	220	198	207	218	1103
4	Bus	688	701	694	639	787	3508	767	747	722	667	829	3732
5	Mini Truck	1491	920	765	726	795	4697	1505	935	790	761	872	4862
6	Truck 2 / 3 Axle	2349	1276	1002	944	641	6212	2212	1193	961	916	671	5953
7	Trolley Agri Goods	377	243	115	36	41	813	334	292	131	35	37	830
8	Tractor With Container	79	18	19	21	23	160	60	19	19	22	25	145
9	Multi Axle Trailer	489	277	297	367	184	1614	471	270	303	375	191	1609
10	Rickshaw	300	0	0	0	0	300	524	0	0	0	0	524
	Total	23326	14790	12438	12462	14317	77333	22118	14170	12138	12110	14852	75388
	G. Total (Less Rickshaw)	23026	14790	12438	12462	14317	77033	21594	14170	12138	12110	14852	74864

APPENDIX C. Traffic Volume Count from 2008-2028

Table C.1 Traffic volumes for the Life Period of Intervention

S #	CATEGORY	FY 06/ 07	FY 07/ 08	FY 08/ 09	FY 09/ 10	FY 10/ 11	FY 11/ 12	FY 12/ 13	FY 13/ 14	FY 14/ 15	FY 15/ 16	FY 16/ 17	FY 17/ 18	FY 18/ 19	FY 19/ 20	FY 20/ 21	FY 21/ 22	FY 22/ 23	FY 23/ 24	FY 24/ 25	FY 25/ 26	FY 26/ 27	FY 27/ 28
1	Cars/ Jeep & Taxi	31925	38332	40181	43755	46505	48200	46881	46930	48807	50759	52790	54901	57098	59381	61757	64227	66796	69468	72247	75136	78142	81268
2	Wagon	8123	8076	8158	10141	12497	13538	12064	9727	10116	10521	10942	11379	11834	12308	12800	13312	13845	14398	14974	15573	16196	16844
3	Bus upto 30 Seats	1573	1710	1792	1170	1112	1173	1083	1104	1148	1194	1242	1292	1343	1397	1453	1511	1571	1634	1700	1768	1838	1912
4	Bus	4220	4356	4264	3882	3467	3467	3508	3728	3877	4032	4193	4361	4536	4717	4906	5102	5306	5518	5739	5969	6207	6456
5	Mini Truck	2696	3550	3541	3864	4052	4501	4697	4845	5039	5240	5450	5668	5895	6130	6376	6631	6896	7172	7459	7757	8067	8390
6	Truck 2/3 Axle	6944	7811	6450	6931	6059	5998	6212	5963	6202	6450	6708	6976	7255	7545	7847	8161	8487	8827	9180	9547	9929	10326
7	Trolley Agri Goods	881	900	795	829	726	809	813	821	854	888	924	960	999	1039	1080	1124	1169	1215	1264	1314	1367	1422
8	Tractor With Container	207	220	190	216	173	174	160	144	150	156	162	168	175	182	189	197	205	213	222	231	240	249
9	Multi axle Trailer	1250	1466	1242	1318	1396	1519	1614	1605	1669	1736	1805	1878	1953	2031	2112	2197	2284	2376	2471	2570	2672	2779
10	Rickshaw	3676	3024	3616	4140	2384	1382	300	525	546	568	591	614	639	664	691	718	747	777	808	841	874	909
	Total	**61495**	**69445**	**70229**	**76246**	**78371**	**80761**	**77332**	**75392**	**78408**	**81544**	**84806**	**88198**	**91726**	**95395**	**99211**	**103179**	**107306**	**111599**	**116063**	**120705**	**125533**	**130555**
	%age Increase		12.93	1.13	8.57	2.79	3.05	-4.25	-2.51	4	4	4	4	4	4	4	4	4	4	4	4	4	4

APPENDIX D. CPI Forecasting

Table D.1 CPI Data

YEAR	CPI VALUE	YEAR	CPI VALUE	YEAR	CPI VALUE
1960	3.71	**1978**	13.59	**1996**	60.52
1961	3.78	**1979**	14.72	**1997**	67.41
1962	3.76	**1980**	16.48	**1998**	71.61
1963	3.81	**1981**	18.43	**1999**	74.57
1964	3.97	**1982**	19.52	**2000**	77.83
1965	4.19	**1983**	20.76	**2001**	80.28
1966	4.49	**1984**	22.03	**2002**	82.92
1967	4.8	**1985**	23.36	**2003**	85.34
1968	4.81	**1986**	24.08	**2004**	91.69
1969	4.96	**1987**	25.21	**2005**	100
1970	5.23	**1988**	27.43	**2006**	107.92
1971	5.47	**1989**	29.59	**2007**	116.12
1972	5.76	**1990**	32.26	**2008**	139.68
1973	7.09	**1991**	36.07	**2009**	158.74
1974	8.98	**1992**	39.5	**2010**	180.78
1975	10.85	**1993**	43.44	**2011**	202.32
1976	11.63	**1994**	48.81	**2012**	215.598
1977	12.81	**1995**	54.83	**2013**	233.856

Table D.2 Future values of CPI

YEAR	CPI VALUE	YEAR	CPI VALUE	YEAR	CPI VALUE
2014	253.661	**2020**	413.124	**2026**	672.833
2015	275.143	**2021**	448.11	**2027**	729.814
2016	298.444	**2022**	486.06	**2028**	791.619
2017	323.718	**2023**	527.223	**2029**	858.659
2018	351.133	**2024**	571.872	**2030**	931.377
2019	380.869	**2025**	620.302	**2031**	1010.25

APPENDIX E. Tables representing Travel Time saved

Table E.1 Travel Time Saving Section 1 for LTV

Year	Capacity	Free Flow Speed	Free Flow Speed	AADT	AWDT	Total Capacity	AWDT/Capacity	Speed	Travel Time	Travel Time incl. TP	Travel Time
	(Veh/hr/lane)	KMs/hr	(miles/hr)						(Minutes)	(Minutes)	Hours
Before Intervention	1800	75	46.605	10338	11372	3600	0.24	37	9.26	9.26	0.154333333
2007	2100	100	62.14	13784	15162	8400	1.81	59.3	5.78	6.78	0.113
2008	2100	100	62.14	16040	17644	8400	2.10	59.1	5.80	6.80	0.1133
2009	2100	100	62.14	16485	18134	8400	2.16	59.05	5.80	6.80	0.1134
2010	2100	100	62.14	18087	19896	8400	2.37	58.97	5.81	6.81	0.1135
2011	2100	100	62.14	18849	20734	8400	2.47	58.94	5.81	6.81	0.1135
2012	2100	100	62.14	18298	20128	8400	2.40	58.91	5.82	6.82	0.1136
2013	2100	100	62.14	17248	18973	8400	2.26	58.88	5.82	6.82	0.1136
2014	2100	100	62.14	15985	17584	8400	2.09	58.85	5.82	6.82	0.1137
2015	2100	100	62.14	16624	18286	8400	2.18	58.82	5.82	6.82	0.1137
2016	2100	100	62.14	17289	19018	8400	2.26	58.79	5.83	6.83	0.1138
2017	2100	100	62.14	17981	19779	8400	2.35	58.78	5.83	6.83	0.1138
2018	2100	100	62.14	18700	20570	8400	2.45	58.77	5.83	6.83	0.1138
2019	2100	100	62.14	19448	21393	8400	2.55	58.76	5.83	6.83	0.1138
2020	2100	100	62.14	20226	22248	8400	2.65	58.75	5.83	6.83	0.1139
2021	2100	100	62.14	21035	23138	8400	2.75	58.74	5.83	6.83	0.1139
2022	2100	100	62.14	21876	24064	8400	2.86	58.74	5.83	6.83	0.1139
2023	2100	100	62.14	22751	25026	8400	2.98	58.7	5.84	6.84	0.1139
2024	2100	100	62.14	23661	26027	8400	3.10	58.65	5.84	6.84	0.1140
2025	2100	100	62.14	24608	27068	8400	3.22	58.6	5.85	6.85	0.1141
2026	2100	100	62.14	25592	28151	8400	3.35	58.55	5.85	6.85	0.1142
2027	2100	100	62.14	26616	29277	8400	3.49	58.5	5.86	6.86	0.1143
2028	2100	100	62.14	27680	30448	8400	3.62	58.35	5.87	6.87	0.1145

Table E.2 Travel Time Saving Section 1 for HTV

Year	Capacity	Free Flow Speed	Free Flow Speed	AADT	AWDT	Total Capacity	AWDT/Capacity	Speed	Travel Time	Travel Time incl. TP	Travel Time
	(Veh/hr/lane)	KMs/hr	(miles/hr)						(Minutes)	(Minutes)	Hours
Before Intervention	1800	65	40.391	5572	6129	3600	0.13	36	9.52	9.5167	0.1586
2007	2100	90	55.926	5804	6384	8400	0.76	59.74	5.73	6.7349	0.1122
2008	2100	90	55.926	6105	6716	8400	0.80	59.7	5.74	6.7387	0.1123
2009	2100	90	55.926	5722	6294	8400	0.75	59.76	5.73	6.7329	0.1122
2010	2100	90	55.926	6028	6631	8400	0.79	59.71	5.74	6.7377	0.1123
2011	2100	90	55.926	5418	5960	8400	0.71	59.84	5.73	6.7253	0.1121
2012	2100	90	55.926	5615	6177	8400	0.74	59.77	5.73	6.7320	0.1122
2013	2100	90	55.926	5777	6355	8400	0.76	59.75	5.73	6.7339	0.1122
2014	2100	90	55.926	5609	6170	8400	0.73	59.82	5.73	6.7272	0.1121
2015	2100	90	55.926	5833	6417	8400	0.76	59.75	5.73	6.7339	0.1122
2016	2100	90	55.926	6067	6673	8400	0.79	59.71	5.74	6.7377	0.1123
2017	2100	90	55.926	6309	6940	8400	0.83	59.5	5.76	6.7580	0.1126
2018	2100	90	55.926	6562	7218	8400	0.86	59.52	5.76	6.7560	0.1126
2019	2100	90	55.926	6824	7507	8400	0.89	59.53	5.76	6.7551	0.1126
2020	2100	90	55.926	7097	7807	8400	0.93	59.56	5.75	6.7522	0.1125
2021	2100	90	55.926	7381	8119	8400	0.97	59.57	5.75	6.7512	0.1125
2022	2100	90	55.926	7676	8444	8400	1.01	59.55	5.75	6.7531	0.1126
2023	2100	90	55.926	7983	8782	8400	1.05	59.53	5.76	6.7551	0.1126
2024	2100	90	55.926	8303	9133	8400	1.09	59.5	5.76	6.7580	0.1126
2025	2100	90	55.926	8635	9498	8400	1.13	59.52	5.76	6.7560	0.1126
2026	2100	90	55.926	8980	9878	8400	1.18	59.49	5.76	6.7590	0.1126
2027	2100	90	55.926	9339	10273	8400	1.22	59.46	5.76	6.7619	0.1127
2028	2100	90	55.926	9713	10684	8400	1.27	59.43	5.76	6.7648	0.1127

Table E.3 Travel Time Saving Section 2 for LTV

Year	Capacity	Free Flow Speed	Free Flow Speed	AADT	AWDT	Total Capacity	AWDT/Capacity	Speed	Travel Time	Travel Time incl. TP	Travel Time
	(Veh/hr/lane)	KMs/hr	(miles/hr)						(Minutes)	Minutes	Hours
Before Intervention	1800	75	46.605	6915	7606	3600	0.16	39	23.5385	23.5385	0.3923
2007	2100	100	62.14	7203	7923	8400	0.94	59.4	15.4545	16.4545	0.2742
2008	2100	100	62.14	8047	8852	8400	1.05	59.37	15.4624	16.4624	0.2744
2009	2100	100	62.14	7874	8661	8400	1.03	59.34	15.4702	16.4702	0.2745
2010	2100	100	62.14	9638	10602	8400	1.26	59.31	15.4780	16.4780	0.2746
2011	2100	100	62.14	11280	12408	8400	1.48	59.28	15.4858	16.4858	0.2748
2012	2100	100	62.14	11677	12845	8400	1.53	59.25	15.4937	16.4937	0.2749
2013	2100	100	62.14	11145	12260	8400	1.46	59.22	15.5015	16.5015	0.2750
2014	2100	100	62.14	10496	11546	8400	1.37	59.19	15.5094	16.5094	0.2752
2015	2100	100	62.14	10196	11216	8400	1.34	59.16	15.5172	16.5172	0.2753
2016	2100	100	62.14	10604	11664	8400	1.39	59.2	15.5068	16.5068	0.2751
2017	2100	100	62.14	11028	12131	8400	1.44	59.3	15.4806	16.4806	0.2747
2018	2100	100	62.14	11469	12616	8400	1.50	58.47	15.7004	16.7004	0.2783
2019	2100	100	62.14	11928	13121	8400	1.56	58.5	15.6923	16.6923	0.2782
2020	2100	100	62.14	12405	13645	8400	1.62	58.53	15.6843	16.6843	0.2781
2021	2100	100	62.14	12901	14191	8400	1.69	58.56	15.6762	16.6762	0.2779
2022	2100	100	62.14	13417	14759	8400	1.76	58.59	15.6682	16.6682	0.2778
2023	2100	100	62.14	13954	15349	8400	1.83	58.62	15.6602	16.6602	0.2777
2024	2100	100	62.14	14512	15963	8400	1.90	58.65	15.6522	16.6522	0.2775
2025	2100	100	62.14	15093	16602	8400	1.98	58.68	15.6442	16.6442	0.2774
2026	2100	100	62.14	15696	17266	8400	2.06	58.71	15.6362	16.6362	0.2773
2027	2100	100	62.14	16324	17957	8400	2.14	58.74	15.6282	16.6282	0.2771
2028	2100	100	62.14	16977	18675	8400	2.22	58.49	15.6950	16.6950	0.2782

Table E.4 Travel Time Saving Section 2 for HTV

Year	Capacity	Free Flow Speed	Free Flow Speed	AADT	AWDT	Total Capacity	AWDT/Capacity	Speed	Travel Time	Travel Time incl. TP	Travel Time
	(Veh/hr/lane)	KMs/hr	(miles/hr)						(Minutes)	Minutes	Hours
Before Intervention	1800	65	40.391	3454	3799	3600	0.08	39	23.54	23.54	0.39
2007	2100	90	55.926	3598	3958	8400	0.47	59.89	15.33	16.33	0.27
2008	2100	90	55.926	4130	4543	8400	0.54	59.87	15.33	16.33	0.27
2009	2100	90	55.926	3471	3818	8400	0.45	59.92	15.32	16.32	0.27
2010	2100	90	55.926	3758	4134	8400	0.49	59.91	15.32	16.32	0.27
2011	2100	90	55.926	3487	3836	8400	0.46	59.88	15.33	16.33	0.27
2012	2100	90	55.926	3604	3964	8400	0.47	59.88	15.33	16.33	0.27
2013	2100	90	55.926	3644	4008	8400	0.48	59.9	15.33	16.33	0.27
2014	2100	90	55.926	3676	4044	8400	0.48	59.9	15.33	16.33	0.27
2015	2100	90	55.926	3823	4205	8400	0.50	59.87	15.33	16.33	0.27
2016	2100	90	55.926	3976	4374	8400	0.52	59.87	15.33	16.33	0.27
2017	2100	90	55.926	4135	4548	8400	0.54	59.86	15.34	16.34	0.27
2018	2100	90	55.926	4300	4730	8400	0.56	59.86	15.34	16.34	0.27
2019	2100	90	55.926	4472	4920	8400	0.59	59.7	15.38	16.38	0.27
2020	2100	90	55.926	4651	5116	8400	0.61	59.65	15.39	16.39	0.27
2021	2100	90	55.926	4837	5321	8400	0.63	59.62	15.40	16.40	0.27
2022	2100	90	55.926	5031	5534	8400	0.66	59.61	15.40	16.40	0.27
2023	2100	90	55.926	5232	5755	8400	0.69	59.61	15.40	16.40	0.27
2024	2100	90	55.926	5441	5985	8400	0.71	59.6	15.40	16.40	0.27
2025	2100	90	55.926	5659	6225	8400	0.74	59.6	15.40	16.40	0.27
2026	2100	90	55.926	5885	6474	8400	0.77	59.59	15.41	16.41	0.27
2027	2100	90	55.926	6121	6733	8400	0.80	59.59	15.41	16.41	0.27
2028	2100	90	55.926	6366	7002	8400	0.83	59.59	15.41	16.41	0.27

Table E.5 Travel Time Saving Section 3 for LTV

Year	Capacity	Free Flow Speed	Free Flow Speed	AADT	AWDT	Total Capacity	AWDT/ Capacity	Speed	Travel Time	Travel Time incl. TP	Travel Time
	(Veh/hr/lane)	KMs/hr	(miles/hr)						(Minutes)	Minutes	Hours
Before Intervention	1800	70	43.498	4169	4585	3600	0.10	38	21.3632	21.3632	0.3561
2007	2100	100	62.14	5558	6114	8400	0.73	59.85	13.5639	14.5639	0.2427
2008	2100	100	62.14	6649	7314	8400	0.87	59.75	13.5866	14.5866	0.2431
2009	2100	100	62.14	7357	8093	8400	0.96	59.65	13.6094	14.6094	0.2435
2010	2100	100	62.14	8388	9227	8400	1.10	59.5	13.6437	14.6437	0.2441
2011	2100	100	62.14	9008	9909	8400	1.18	59.47	13.6506	14.6506	0.2442
2012	2100	100	62.14	9628	10591	8400	1.26	59.43	13.6598	14.6598	0.2443
2013	2100	100	62.14	9370	10307	8400	1.23	59.4	13.6667	14.6667	0.2444
2014	2100	100	62.14	9015	9917	8400	1.18	59.37	13.6736	14.6736	0.2446
2015	2100	100	62.14	9376	10314	8400	1.23	59.34	13.6805	14.6805	0.2447
2016	2100	100	62.14	9751	10726	8400	1.28	59.31	13.6874	14.6874	0.2448
2017	2100	100	62.14	10141	11155	8400	1.33	59.28	13.6943	14.6943	0.2449
2018	2100	100	62.14	10547	11601	8400	1.38	59.25	13.7013	14.7013	0.2450
2019	2100	100	62.14	10969	12065	8400	1.44	59.24	13.7036	14.7036	0.2451
2020	2100	100	62.14	11407	12548	8400	1.49	59.23	13.7059	14.7059	0.2451
2021	2100	100	62.14	11864	13050	8400	1.55	59.22	13.7082	14.7082	0.2451
2022	2100	100	62.14	12338	13572	8400	1.62	59.21	13.7105	14.7105	0.2452
2023	2100	100	62.14	12832	14115	8400	1.68	59.21	13.7105	14.7105	0.2452
2024	2100	100	62.14	13345	14679	8400	1.75	59.2	13.7128	14.7128	0.2452
2025	2100	100	62.14	13879	15267	8400	1.82	59.2	13.7128	14.7128	0.2452
2026	2100	100	62.14	14434	15877	8400	1.89	59.2	13.7128	14.7128	0.2452
2027	2100	100	62.14	15011	16512	8400	1.97	59.2	13.7128	14.7128	0.2452
2028	2100	100	62.14	15612	17173	8400	2.04	59.18	13.7175	14.7175	0.2453

Table E.6 Travel Time Saving Section 3 for HTV

Year	Capacity	Free Flow Speed	Free Flow Speed	AADT	AWDT	Total Capacity	AWDT/ Capacity	Speed	Travel Time	Travel Time incl. TP	Travel Time
	(Veh/hr/lane)	KMs/hr	(miles/hr)						(Minutes)	Minutes	Hours
Before Intervention	1800	65	40.391	2192	2411	3600	0.05	39	20.8154	20.8154	0.3469
2007	2100	90	55.926	2922	3214	8400	0.38	60	13.5300	14.5300	0.2422
2008	2100	90	55.926	3354	3689	8400	0.44	59.95	13.5413	14.5413	0.2424
2009	2100	90	55.926	3162	3478	8400	0.41	59.9	13.5526	14.5526	0.2425
2010	2100	90	55.926	3119	3431	8400	0.41	59.9	13.5526	14.5526	0.2425
2011	2100	90	55.926	2990	3289	8400	0.39	59.97	13.5368	14.5368	0.2423
2012	2100	90	55.926	2971	3268	8400	0.39	59.97	13.5368	14.5368	0.2423
2013	2100	90	55.926	3068	3375	8400	0.40	59.96	13.5390	14.5390	0.2423
2014	2100	90	55.926	3124	3436	8400	0.41	59.9	13.5526	14.5526	0.2425
2015	2100	90	55.926	3249	3574	8400	0.43	59.96	13.5390	14.5390	0.2423
2016	2100	90	55.926	3379	3717	8400	0.44	59.95	13.5413	14.5413	0.2424
2017	2100	90	55.926	3514	3866	8400	0.46	59.89	13.5549	14.5549	0.2426
2018	2100	90	55.926	3655	4020	8400	0.48	59.96	13.5390	14.5390	0.2423
2019	2100	90	55.926	3801	4181	8400	0.50	59.85	13.5639	14.5639	0.2427
2020	2100	90	55.926	3953	4348	8400	0.52	59.87	13.5594	14.5594	0.2427
2021	2100	90	55.926	4111	4522	8400	0.54	59.85	13.5639	14.5639	0.2427
2022	2100	90	55.926	4275	4703	8400	0.56	59.83	13.5684	14.5684	0.2428
2023	2100	90	55.926	4446	4891	8400	0.58	59.81	13.5730	14.5730	0.2429
2024	2100	90	55.926	4624	5087	8400	0.61	59.79	13.5775	14.5775	0.2430
2025	2100	90	55.926	4809	5290	8400	0.63	59.77	13.5821	14.5821	0.2430
2026	2100	90	55.926	5002	5502	8400	0.65	59.75	13.5866	14.5866	0.2431
2027	2100	90	55.926	5202	5722	8400	0.68	59.73	13.5912	14.5912	0.2432
2028	2100	90	55.926	5410	5951	8400	0.71	59.71	13.5957	14.5957	0.2433

Table E.7 Travel Time Saving Section 4 for LTV

Year	Capacity	Free Flow Speed	Free Flow Speed	AADT	AWDT	Total Capacity	AWDT/Capacity	Speed	Travel Time	Travel Time incl. TP	Travel Time
	(Veh/hr/lane)	KMs/hr	(miles/hr)						(Minutes)	Minutes	Hours
Before Intervention	1800	70	43.498	3820	4202	3600	0.09	39	29.8462	29.8462	0.4974
2007	2100	100	62.14	5093	5602	8400	0.67	59.7	19.4975	20.4975	0.3416
2008	2100	100	62.14	6194	6813	8400	0.81	59.62	19.5236	20.5236	0.3421
2009	2100	100	62.14	6870	7557	8400	0.90	59.59	19.5335	20.5335	0.3422
2010	2100	100	62.14	7926	8719	8400	1.04	59.57	19.5400	20.5400	0.3423
2011	2100	100	62.14	8666	9533	8400	1.13	59.52	19.5565	20.5565	0.3426
2012	2100	100	62.14	9840	10824	8400	1.29	59.47	19.5729	20.5729	0.3429
2013	2100	100	62.14	9535	10489	8400	1.25	59.45	19.5795	20.5795	0.3430
2014	2100	100	62.14	9126	10039	8400	1.20	59.42	19.5894	20.5894	0.3432
2015	2100	100	62.14	9491	10440	8400	1.24	59.39	19.5993	20.5993	0.3433
2016	2100	100	62.14	9871	10858	8400	1.29	59.36	19.6092	20.6092	0.3435
2017	2100	100	62.14	10265	11292	8400	1.34	59.33	19.6191	20.6191	0.3437
2018	2100	100	62.14	10676	11744	8400	1.40	59.3	19.6290	20.6290	0.3438
2019	2100	100	62.14	11103	12213	8400	1.45	59.27	19.6389	20.6389	0.3440
2020	2100	100	62.14	11547	12702	8400	1.51	59.24	19.6489	20.6489	0.3441
2021	2100	100	62.14	12009	13210	8400	1.57	59.23	19.6522	20.6522	0.3442
2022	2100	100	62.14	12490	13738	8400	1.64	59.22	19.6555	20.6555	0.3443
2023	2100	100	62.14	12989	14288	8400	1.70	59.21	19.6588	20.6588	0.3443
2024	2100	100	62.14	13509	14860	8400	1.77	59.15	19.6788	20.6788	0.3446
2025	2100	100	62.14	14049	15454	8400	1.84	59.12	19.6888	20.6888	0.3448
2026	2100	100	62.14	14611	16072	8400	1.91	59.07	19.7054	20.7054	0.3451
2027	2100	100	62.14	15195	16715	8400	1.99	59.02	19.7221	20.7221	0.3454
2028	2100	100	62.14	15803	17384	8400	2.07	58.95	19.7455	20.7455	0.3458

Table E.8 Travel Time Saving Section 4 for HTV

Year	Capacity	Free Flow Speed	Free Flow Speed	AADT	AWDT	Total Capacity	AWDT/Capacity	Speed	Travel Time	Travel Time incl. TP	Travel Time
	(Veh/hr/lane)	KMs/hr	(miles/hr)						(Minutes)	Minutes	Hours
Before Intervention	1800	65	40.391	1955	2150	3600	0.04	39.5	29.4684	29.4684	0.4911
2007	2100	90	55.926	2606	2867	8400	0.34	59.99	19.4032	20.4032	0.3401
2008	2100	90	55.926	3189	3508	8400	0.42	59.95	19.4162	20.4162	0.3403
2009	2100	90	55.926	2866	3153	8400	0.38	59.97	19.4097	20.4097	0.3402
2010	2100	90	55.926	2762	3038	8400	0.36	59.98	19.4065	20.4065	0.3401
2011	2100	90	55.926	2663	2929	8400	0.35	59.98	19.4065	20.4065	0.3401
2012	2100	90	55.926	2808	3089	8400	0.37	59.98	19.4065	20.4065	0.3401
2013	2100	90	55.926	2927	3220	8400	0.38	59.97	19.4097	20.4097	0.3402
2014	2100	90	55.926	2983	3281	8400	0.39	59.97	19.4097	20.4097	0.3402
2015	2100	90	55.926	3102	3412	8400	0.41	59.92	19.4259	20.4259	0.3404
2016	2100	90	55.926	3226	3549	8400	0.42	59.93	19.4227	20.4227	0.3404
2017	2100	90	55.926	4135	4549	8400	0.54	59.8	19.4649	20.4649	0.3411
2018	2100	90	55.926	4300	4730	8400	0.56	59.78	19.4714	20.4714	0.3412
2019	2100	90	55.926	4472	4920	8400	0.59	59.75	19.4812	20.4812	0.3414
2020	2100	90	55.926	4651	5116	8400	0.61	59.7	19.4975	20.4975	0.3416
2021	2100	90	55.926	4837	5321	8400	0.63	59.68	19.5040	20.5040	0.3417
2022	2100	90	55.926	5031	5534	8400	0.66	59.67	19.5073	20.5073	0.3418
2023	2100	90	55.926	5232	5755	8400	0.69	59.63	19.5204	20.5204	0.3420
2024	2100	90	55.926	5441	5986	8400	0.71	59.6	19.5302	20.5302	0.3422
2025	2100	90	55.926	5659	6225	8400	0.74	59.59	19.5335	20.5335	0.3422
2026	2100	90	55.926	5885	6474	8400	0.77	59.59	19.5335	20.5335	0.3422
2027	2100	90	55.926	6121	6733	8400	0.80	59.59	19.5335	20.5335	0.3422
2028	2100	90	55.926	6366	7002	8400	0.83	59.59	19.5335	20.5335	0.3422

Table E.9 Travel Time Saving Section 5 for LTV

Year	Capacity	Free Flow Speed	Free Flow Speed	AADT	AWDT	Total Capacity	AWDT/ Capacity	Speed	Travel Time	Travel Time incl. TP	Travel Time
	(Veh/hr/lane)	KMs/hr	(miles/hr)							(Minutes)	Hours
Before Intervention	1800	55	34.177	5763	6339	7200	0.07	40	23.5260	23.5300	0.3922
2007	2100	70	43.498	7684	8452	8400	1.01	59.58	15.7946	16.7946	0.2799
2008	2100	70	43.498	9483	10431	8400	1.24	59.58	15.7946	16.7946	0.2799
2009	2100	70	43.498	9754	10729	8400	1.28	59.57	15.7972	16.7972	0.2800
2010	2100	70	43.498	9856	10842	8400	1.29	59.56	15.7999	16.7999	0.2800
2011	2100	70	43.498	11200	12320	8400	1.47	59.55	15.8025	16.8025	0.2800
2012	2100	70	43.498	12295	13525	8400	1.61	59.54	15.8052	16.8052	0.2801
2013	2100	70	43.498	11648	12813	8400	1.53	59.53	15.8078	16.8078	0.2801
2014	2100	70	43.498	12010	13211	8400	1.57	59.5	15.8158	16.8158	0.2803
2015	2100	70	43.498	12490	13739	8400	1.64	59.47	15.8238	16.8238	0.2804
2016	2100	70	43.498	12990	14289	8400	1.70	59.44	15.8318	16.8318	0.2805
2017	2100	70	43.498	13510	14861	8400	1.77	59.41	15.8398	16.8398	0.2807
2018	2100	70	43.498	14050	15455	8400	1.84	59.38	15.8478	16.8478	0.2808
2019	2100	70	43.498	14612	16073	8400	1.91	59.35	15.8558	16.8558	0.2809
2020	2100	70	43.498	15196	16716	8400	1.99	59.25	15.8825	16.8825	0.2814
2021	2100	70	43.498	15804	17385	8400	2.07	59.18	15.9013	16.9013	0.2817
2022	2100	70	43.498	16437	18080	8400	2.15	59.15	15.9094	16.9094	0.2818
2023	2100	70	43.498	17094	18803	8400	2.24	59.12	15.9175	16.9175	0.2820
2024	2100	70	43.498	17778	19556	8400	2.33	59.08	15.9282	16.9282	0.2821
2025	2100	70	43.498	18489	20338	8400	2.42	59.02	15.9444	16.9444	0.2824
2026	2100	70	43.498	19228	21151	8400	2.52	58.98	15.9552	16.9552	0.2826
2027	2100	70	43.498	19998	21997	8400	2.62	58.8	16.0041	17.0041	0.2834
2028	2100	70	43.498	20797	22877	8400	2.72	58.7	16.0313	17.0313	0.2839

Table E.10 Travel Time Saving Section 5 for HTV

Year	Capacity	Free Flow Speed	Free Flow Speed	AADT	AWDT	Total Capacity	AWDT/ Capacity	Speed	Travel Time	Travel Time incl. TP	Travel Time
	(Veh/hr/lane)	KMs/hr	(miles/hr)							(Minutes)	Hours
Before Intervention	1800	55	43.498	2130	2343	7200	0.02	40	23.5260	23.5300	0.3922
2007	2100	70	62.14	2840	3124	8400	0.37	59.95	15.6971	16.6971	0.2783
2008	2100	70	62.14	3234	3557	8400	0.42	59.9	15.7102	16.7102	0.2785
2009	2100	70	62.14	3053	3358	8400	0.40	59.92	15.7049	16.7049	0.2784
2010	2100	70	62.14	2546	2801	8400	0.33	59.99	15.6866	16.6866	0.2781
2011	2100	70	62.14	2431	2674	8400	0.32	60	15.6840	16.6840	0.2781
2012	2100	70	62.14	2575	2833	8400	0.34	59.98	15.6892	16.6892	0.2782
2013	2100	70	62.14	2669	2936	8400	0.35	59.97	15.6918	16.6918	0.2782
2014	2100	70	62.14	2843	3127	8400	0.37	59.95	15.6971	16.6971	0.2783
2015	2100	70	62.14	2957	3253	8400	0.39	59.93	15.7023	16.7023	0.2784
2016	2100	70	62.14	3075	3383	8400	0.40	59.92	15.7049	16.7049	0.2784
2017	2100	70	62.14	3198	3518	8400	0.42	59.89	15.7128	16.7128	0.2785
2018	2100	70	62.14	3326	3659	8400	0.44	59.87	15.7181	16.7181	0.2786
2019	2100	70	62.14	3459	3805	8400	0.45	59.85	15.7233	16.7233	0.2787
2020	2100	70	62.14	3598	3957	8400	0.47	59.83	15.7286	16.7286	0.2788
2021	2100	70	62.14	3742	4116	8400	0.49	59.81	15.7338	16.7338	0.2789
2022	2100	70	62.14	3891	4280	8400	0.51	59.79	15.7391	16.7391	0.2790
2023	2100	70	62.14	4047	4452	8400	0.53	59.77	15.7444	16.7444	0.2791
2024	2100	70	62.14	4209	4630	8400	0.55	59.75	15.7496	16.7496	0.2792
2025	2100	70	62.14	4377	4815	8400	0.57	59.73	15.7549	16.7549	0.2792
2026	2100	70	62.14	4552	5007	8400	0.60	59.71	15.7602	16.7602	0.2793
2027	2100	70	62.14	4734	5208	8400	0.62	59.69	15.7655	16.7655	0.2794
2028	2100	70	62.14	4924	5416	8400	0.64	59.67	15.7707	16.7707	0.2795

Table E.11 Travel Time Savings Section 1

Sr.	Year	Savings	Savings
		Million PKR	2007 PV
1	2007	221.32	221.32
2	2008	219.98	211.51996
3	2009	219.81	203.23085
4	2010	222.52	197.82169
5	2011	222.28	190.00847
6	2012	214.65	176.42331
7	2013	201.44	159.20079
8	2014	190.03	144.40742
9	2015	197.31	144.16979
10	2016	204.94	143.98555
11	2017	212.52	143.57034
12	2018	221.02	143.56885
13	2019	229.83	143.54929
14	2020	239.05	143.56575
15	2021	248.58	143.54614
16	2022	258.45	143.51012
17	2023	268.44	143.32349
18	2024	278.71	143.08086
19	2025	289.55	142.92809
20	2026	300.62	142.6848
21	2027	312.11	142.44113
22	2028	323.17	141.81647
Total Savings		5296.31	3509.68

Table E.12 Travel Time Savings Section 2

Sr.	Year	Savings	Savings
		Million PKR	2007 PV
1	2007	228.99	228.99
2	2008	249.58	239.9851
3	2009	233.83	216.1924
4	2010	247.67	220.1817
5	2011	249.27	213.0769
6	2012	254.84	209.4606
7	2013	246.37	194.706
8	2014	246.18	187.0741
9	2015	255.76	186.8779
10	2016	266.13	186.9773
11	2017	277.08	187.1845
12	2018	284.95	185.0967
13	2019	295.43	184.5223
14	2020	307.03	184.3947
15	2021	319.23	184.3485
16	2022	332.07	184.384
17	2023	345.49	184.4603
18	2024	359.38	184.4956
19	2025	373.91	184.5718
20	2026	388.94	184.6069
21	2027	404.66	184.6828
22	2028	419.40	184.047
Total Savings		6586.18	4300.31

Table E.13 Travel Time Savings Section 3

Sr.	Year	Savings	Savings
		Million PKR	2007 PV
1	2007	209.25	209.25
2	2008	233.62	224.631
3	2009	246.40	227.8082
4	2010	266.06	236.5304
5	2011	284.50	243.1948
6	2012	302.84	248.9154
7	2013	292.40	231.0842
8	2014	275.91	209.6662
9	2015	287.05	209.7461
10	2016	298.31	209.5917
11	2017	309.77	209.2698
12	2018	322.34	209.3828
13	2019	334.57	208.974
14	2020	348.00	209.0006
15	2021	361.74	208.8931
16	2022	376.01	208.7855
17	2023	390.93	208.7183
18	2024	406.35	208.6106
19	2025	422.47	208.5434
20	2026	439.23	208.4761
21	2027	456.65	208.4087
22	2028	474.58	208.2603
Total Savings		7338.97	4755.74

Table E.14 Travel Time Savings Section 4

Sr.	Year	Savings	Savings
		Million PKR	2007 PV
1	2007	306.63	306.63
2	2008	336.27	323.3366
3	2009	363.12	335.7212
4	2010	383.51	340.9355
5	2011	409.88	350.3694
6	2012	461.32	379.1697
7	2013	447.98	354.0442
8	2014	403.96	306.9791
9	2015	419.55	306.5602
10	2016	436.12	306.4119
11	2017	452.41	305.63
12	2018	470.07	305.3454
13	2019	488.34	305.0152
14	2020	507.17	304.5936
15	2021	527.19	304.4378
16	2022	548.08	304.3275
17	2023	569.54	304.0803
18	2024	591.29	303.554
19	2025	614.46	303.3134
20	2026	638.35	302.9879
21	2027	663.17	302.6619
22	2028	688.65	302.2046
Total Savings		10727.04	6958.31

Table E.15 Travel Time Savings Section 5

Sr.	Year	Savings	Savings
		Million PKR	2007 PV
1	2007	308.83	308.83
2	2008	352.19	338.6476
3	2009	357.76	330.7662
4	2010	322.01	286.2635
5	2011	351.11	300.1324
6	2012	401.06	329.6383
7	2013	373.79	295.4115
8	2014	357.66	271.7956
9	2015	371.59	271.5195
10	2016	386.12	271.2858
11	2017	401.10	270.9665
12	2018	416.71	270.6897
13	2019	432.94	270.4126
14	2020	449.05	269.6868
15	2021	466.08	269.1518
16	2022	484.23	268.8732
17	2023	503.07	268.5944
18	2024	522.53	268.2508
19	2025	542.47	267.7776
20	2026	563.44	267.4331
21	2027	583.23	266.1786
22	2028	604.88	265.4404
Total Savings		9551.85	6227.75

APPENDIX F. Crash Reduction and Accident Modification Factors

Table A6.1 Crash Reduction Factors: All Highways

Activity Category	Specific Activity	Crash Reduction Factor (%) All Crashes
Channelization	Channelize intersection	23
	Provide left-turn lane (with signal)	24
	Provide left-turn lane (without signal)	40
	Install two-way left turn in median	34
	Add mountable median	15
	Add nonmountable median	25
	Provide right-turn-lane	28
	Increase turn-lane length	28
	Horizontal alignment changes	50
Geometric improvements	Gentler horizontal curve	
	Change in horizontal curvature	
	20 to 10°	48
	15 to 5°	63
	10 to 5°	45
	Improve vertical curve	43
	Improve sight distance at intersection	31
	Superelevation	46
Median device installation	Install median barrier (general)	25
	Install raised median	23
	Add flush median	52
	Add flush median with refuge for left turns	44
Widening of lane/shoulder, shoulder paving	Widen lane	28
	Widen paved shoulder	29
	Widen unpaved shoulder	22
	Pave shoulder	17
	Stabilize shoulder	24
Lane additions	Add acceleration/deceleration lane	16
	Add lanes	23
	Add turning lane	17
Bridge improvements	Bridge replacement	46
	Bridge widening	48
	Bridge deck repair	14
	Bridge rail upgrade	20
Intersection improvements	Increase turning radii	13
	improve sight distance	33
Freeway improvements	Construct interchange	57
	Modify entrance/exit ramp	25
	Construct frontage road	35

Table A6.1 (*continued*)

Activity Category	Specific Activity	Crash Reduction Factor (%) All Crashes
Traffic signal improvements	Install sign	27
	Change 2WSC to signal	28
	Change 2WSC to signal and add lane	36
	General upgrade of existing signal system	25
	Replace lenses with larger ones (12 in.)	12
	Improve signal phasing	25
	Improve signal timing	12
	Add exclusive left-turn phase (protected)	29
	Install/improve pedestrian signal	23
	Remove unwarranted signal	66
Guardrail improvements	Install guardrail	20
	Upgrade guardrail	10
	Install guardrail at bridge	24
	Install guardrail at outer lane in curve	63
	Install guardrail at culverts	27
Pavement improvements	General pavement treatment	25
	Groove pavement	19
	Resurface with skid-resistant material	10
	Resurfacing (general)	20
	Install rumble strips	30
	Groove shoulder	25
Roadside improvements	Relocate fixed objects	40
	Install impact attenuators	30
	Flatten side slope	25

Source: Harkey et al. (2004).

APPENDIX G. Safety Cost Calculations for Before and after Intervention

Table G.1 Safety Cost before Intervention

FSD-SHP Section

Year	Length	Length	AADT	Annual VMT	Fatal Crash Rate	Non-Fatal Crash Rate	Total Fatal Crashes	Total Non-Fatal Crashes	Fatal Crash Cost	Non-Fatal Crash Cost	Unit Fatal Crash Cost	Unit Non-fatal Crash Cost	Total Fatal Crash Cost	Total Non-Fatal Crash Cost	Total Cost	Total Cost	Cost
	Km	Miles			(100M)	(100M)			2007 $	2007 $	PKR 2007	PKR 2007	PKR 2007	PKR 2007		Million Rupees	2007 PV
2006	86.76	53.912	35467.5	7	4.61	22.87	32.2	159.6	75950	19530	4,557,000	1,171,800	146,735,400	187,019,280	333,754,680	333.76	347.1052

SHP-LHR Section

Year	Length	Length	AADT	Annual VMT	Fatal Crash Rate	Non-Fatal Crash Rate	Fatal Crashes	Injured Crashes	Fatal Crash Cost	Non-Fatal Crash Cost	Unit Fatal Crash Cost	Unit Non-fatal Crash Cost	Total Fatal Crash Cost	Total Non-Fatal Crash Cost	Total Cost	Total Cost	Cost
	KM	Miles			(100M)	(100M)			2007 $	2007 $	PKR 2007	PKR 2007	PKR 2007	PKR 2007		Million Rupees	2007 PV
2006	25.24	15.6841	8423	0.48	23.23	217.76	11.2	105	75950	19530	4,557,000	1,171,800	51,038,400	123,039,000	174,077,400	174.08	181.0

Table G.2 Safety Cost after Intervention on SHP-FSD Section

Year	Length	Length	AADT	Annual VMT	Fatal Crash Rate	Non-Fatal Crash Rate	Total Fatal Crashes	Total Non-Fatal Crashes	Fatal Crash Cost	Non-Fatal Crash Cost	Unit Fatal Crash Cost	Unit Non-fatal Crash Cost	Total Fatal Crash Cost	Total Non-Fatal Crash Cost	Total Cost	Total Cost	Total Cost
	Km	Miles			(100M)	(100M)			2007 $	2007 $	PKR 2007	PKR 2007	PKR 2007	PKR 2007	Rupees	Million Rupees	2007 PV
2007	86.76	53.912664	50966	10.03	2.29	11.37	23	114	75950	19530	4,557,000	1,171,800	104,811,000	133,585,200	238,396,200	238.40	238.40
2008	86.76	53.912664	56694	11.16	3.32	20.53	37	229	75950	19530	4,557,000	1,171,800	168,609,000	268,342,200	436,951,200	436.95	420.15
2009	86.76	53.912664	57387	11.29	2.30	18.68	26	211	75950	19530	4,557,000	1,171,800	118,482,000	247,249,800	365,731,800	365.73	338.14
2010	86.76	53.912664	63843	12.56	1.59	27.78	20	349	75950	19530	4,557,000	1,171,800	91,140,000	408,958,200	500,098,200	500.10	444.59
2011	86.76	53.912664	64742	12.74	2.43	24.25	31	309	75950	19530	4,557,000	1,171,800	141,267,000	362,086,200	503,353,200	503.35	430.27
2012	86.76	53.912664	65894	12.97	0.69	17.58	9	228	75950	19530	4,557,000	1,171,800	41,013,000	267,170,400	308,183,400	308.18	253.30
2013	86.76	53.912664	63016	12.40	1.61	22.42	20	278	75950	19530	4,557,000	1,171,800	91,140,000	325,760,400	416,900,400	416.90	329.48
2014	86.76	53.912664	60536	11.91	0.84	14.86	10	177	75950	19530	4,557,000	1,171,800	45,570,000	207,408,600	252,978,600	252.98	192.24
2015	86.76	53.912664	62957	12.39	1.89	19.68	23	244	75950	19530	4,557,000	1,171,800	106,446,614	285,758,907	392,205,522	392.21	286.58
2016	86.76	53.912664	65476	12.88	1.89	19.68	24	254	75950	19530	4,557,000	1,171,800	110,969,822	297,127,360	408,097,182	408.10	286.72
2017	86.76	53.912664	68095	13.40	1.89	19.68	25	264	75950	19530	4,557,000	1,171,800	115,408,615	309,012,454	424,421,069	424.42	286.72
2018	86.76	53.912664	70819	13.94	1.89	19.68	26	274	75950	19530	4,557,000	1,171,800	120,024,959	321,372,952	441,397,912	441.40	286.72
2019	86.76	53.912664	73651	14.49	1.89	19.68	27	285	75950	19530	4,557,000	1,171,800	124,825,958	334,227,871	459,053,828	459.05	286.72
2020	86.76	53.912664	76597	15.07	1.89	19.68	28	297	75950	19530	4,557,000	1,171,800	129,818,996	347,596,985	477,415,981	477.42	286.72
2021	86.76	53.912664	79661	15.68	1.89	19.68	30	309	75950	19530	4,557,000	1,171,800	135,011,756	361,500,865	496,512,621	496.51	286.72
2022	86.76	53.912664	82848	16.30	1.89	19.68	31	321	75950	19530	4,557,000	1,171,800	140,412,226	375,960,899	516,373,125	516.37	286.72
2023	86.76	53.912664	86162	16.95	1.89	19.68	32	334	75950	19530	4,557,000	1,171,800	146,028,715	390,999,335	537,028,051	537.03	286.72
2024	86.76	53.912664	89608	17.63	1.89	19.68	33	347	75950	19530	4,557,000	1,171,800	151,869,864	406,639,309	558,509,173	558.51	286.72
2025	86.76	53.912664	93192	18.34	1.89	19.68	35	361	75950	19530	4,557,000	1,171,800	157,944,658	422,904,881	580,849,539	580.85	286.72
2026	86.76	53.912664	96920	19.07	1.89	19.68	36	375	75950	19530	4,557,000	1,171,800	164,262,445	439,821,076	604,083,521	604.08	286.72
2027	86.76	53.912664	100797	19.83	1.89	19.68	37	390	75950	19530	4,557,000	1,171,800	170,832,942	457,413,919	628,246,862	628.25	286.72
2028	86.76	53.912664	104829	20.63	1.89	19.68	39	406	75950	19530	4,557,000	1,171,800	177,666,260	475,710,476	653,376,736	653.38	286.72
2029	86.76	53.912664	109022	21.45	1.89	19.68	41	422	75950	19530	4,557,000	1,171,800	184,772,911	494,738,895	679,511,806	679.51	286.72
2030	86.76	53.912664	113383	22.31	1.89	19.68	42	439	75950	19530	4,557,000	1,171,800	192,163,827	514,528,451	706,692,278	706.69	286.72
2031	86.76	53.912664	117918	23.20	1.89	19.68	44	457	75950	19530	4,557,000	1,171,800	199,850,380	535,109,589	734,959,969	734.96	286.72
																Total Cost	**7234.00**

Table G.3 Safety Cost after Intervention on LHR-SHP Section

Year	Length	Length	AADT	Annual VMT	Fatal Crash Rate	Non-Fatal Crash Rate	Fatal Crashes	Injured Crashes	Fatal Crash Cost	Non-Fatal Crash Cost	Unit Fatal Crash Cost	Unit Non-fatal Crash Cost	Total Fatal Crash Cost	Total Non-Fatal Crash Cost	Total Cost	Total Cost	Total Cost
	KM	Miles			(100M)	(100M)			2007 $	2007 $	PKR 2007	PKR 2007	PKR 2007	PKR 2007	Rupees	Million Rupees	2007 PV
2007	25.24	15.684136	10529	0.60	13.27	124.43	8	75	75950	19530	4,557,000	1,171,800	36,456,000	87,885,000	124,341,000	124.34	124.34
2008	25.24	15.684136	12751	0.73	54.80	430.16	40	314	75950	19530	4,557,000	1,171,800	182,280,000	367,945,200	550,225,200	550.23	529.06
2009	25.24	15.684136	12842	0.74	19.04	282.93	14	208	75950	19530	4,557,000	1,171,800	63,798,000	243,734,400	307,532,400	307.53	284.33
2010	25.24	15.684136	12402	0.71	23.94	161.98	17	115	75950	19530	4,557,000	1,171,800	77,469,000	134,757,000	212,226,000	212.23	188.67
2011	25.24	15.684136	13629	0.78	12.82	80.75	10	63	75950	19530	4,557,000	1,171,800	45,570,000	73,823,400	119,393,400	119.39	102.06
2012	25.24	15.684136	14869	0.85	11.75	83.41	10	71	75950	19530	4,557,000	1,171,800	45,570,000	83,197,800	128,767,800	128.77	105.84
2013	25.24	15.684136	14317	0.82	51.24	236.70	42	194	75950	19530	4,557,000	1,171,800	191,394,000	227,329,200	418,723,200	418.72	330.92
2014	25.24	15.684136	14852	0.85	17.64	216.41	15	184	75950	19530	4,557,000	1,171,800	68,355,000	215,611,200	283,966,200	283.97	207.49
2015	25.24	15.684136	15446	0.88	25.56	202.10	20	179	75950	19530	4,557,000	1,171,800	88,861,500	209,402,443	298,263,943	298.26	209.56
2016	25.24	15.684136	16064	0.92	25.56	202.10	24	186	75950	19530	4,557,000	1,171,800	107,113,685	217,783,458	324,897,144	324.90	219.49
2017	25.24	15.684136	16706	0.96	25.56	202.10	24	193	75950	19530	4,557,000	1,171,800	111,398,233	226,494,797	337,893,029	337.89	219.49
2018	25.24	15.684136	17375	0.99	25.56	202.10	25	201	75950	19530	4,557,000	1,171,800	115,854,162	235,554,589	351,408,751	351.41	228.27
2019	25.24	15.684136	18070	1.03	25.56	202.10	26	209	75950	19530	4,557,000	1,171,800	120,488,328	244,976,772	365,465,101	365.47	228.27
2020	25.24	15.684136	18793	1.08	25.56	202.10	27	217	75950	19530	4,557,000	1,171,800	125,307,861	254,775,843	380,083,705	380.08	228.27
2021	25.24	15.684136	19544	1.12	25.56	202.10	29	226	75950	19530	4,557,000	1,171,800	130,320,176	264,966,877	395,287,053	395.29	228.27
2022	25.24	15.684136	20326	1.16	25.56	202.10	30	235	75950	19530	4,557,000	1,171,800	135,532,983	275,565,552	411,098,535	411.10	228.27
2023	25.24	15.684136	21139	1.21	25.56	202.10	31	245	75950	19530	4,557,000	1,171,800	140,954,302	286,588,174	427,542,476	427.54	228.27
2024	25.24	15.684136	21985	1.26	25.56	202.10	32	254	75950	19530	4,557,000	1,171,800	146,592,474	298,051,701	444,644,175	444.64	228.27
2025	25.24	15.684136	22864	1.31	25.56	202.10	33	265	75950	19530	4,557,000	1,171,800	152,456,173	309,973,769	462,429,942	462.43	228.27
2026	25.24	15.684136	23779	1.36	25.56	202.10	35	275	75950	19530	4,557,000	1,171,800	158,554,420	322,372,720	480,927,140	480.93	228.27
2027	25.24	15.684136	24730	1.42	25.56	202.10	36	286	75950	19530	4,557,000	1,171,800	164,896,597	335,267,629	500,164,226	500.16	228.27
2028	25.24	15.684136	25719	1.47	25.56	202.10	38	298	75950	19530	4,557,000	1,171,800	171,492,461	348,678,334	520,170,795	520.17	228.27
2029	25.24	15.684136	26748	1.53	25.56	202.10	39	309	75950	19530	4,557,000	1,171,800	178,352,159	362,625,467	540,977,627	540.98	228.27
2030	25.24	15.684136	27818	1.59	25.56	202.10	41	322	75950	19530	4,557,000	1,171,800	185,486,246	377,130,486	562,616,732	562.62	228.27
2031	25.24	15.684136	28930	1.66	25.56	202.10	42	335	75950	19530	4,557,000	1,171,800	192,905,696	392,215,705	585,121,401	585.12	228.27
																Total Cost	**5488.74**

Table G.4 Safety Savings on FSD-SHP Section

Sr	Year	Cost before Intervention	Cost after Intervention	Savings Million PKR
1	2007	347.1052	238.40	108.7052
2	2008	347.1052	420.15	-73.0448
3	2009	347.1052	338.14	8.9652
4	2010	347.1052	444.59	-97.4848
5	2011	347.1052	430.27	-83.1648
6	2012	347.1052	253.30	93.8052
7	2013	347.1052	329.48	17.6252
8	2014	347.1052	192.24	154.8652
9	2015	347.1052	286.58	60.5252
10	2016	347.1052	286.72	60.3852
11	2017	347.1052	286.72	60.3852
12	2018	347.1052	286.72	60.3852
13	2019	347.1052	286.72	60.3852
14	2020	347.1052	286.72	60.3852
15	2021	347.1052	286.72	60.3852
16	2022	347.1052	286.72	60.3852
17	2023	347.1052	286.72	60.3852
18	2024	347.1052	286.72	60.3852
19	2025	347.1052	286.72	60.3852
20	2026	347.1052	286.72	60.3852
21	2027	347.1052	286.72	60.3852
22	2028	347.1052	286.72	60.3852
			Total	975.8044

Table G.5 Safety Savings on LHR-SHP Section

Sr	Year	Cost before Intervention	Cost after Intervention	Savings Million PKR
1	2007	181.040496	124.34	56.699496
2	2008	181.040496	529.06	-348.0221963
3	2009	181.040496	284.33	-103.2904951
4	2010	181.040496	188.67	-7.627645215
5	2011	181.040496	102.06	78.9825173
6	2012	181.040496	105.84	75.2027507
7	2013	181.040496	330.92	-149.8825312
8	2014	181.040496	207.49	-26.45082489
9	2015	181.040496	209.56	-28.51579381
10	2016	181.040496	219.49	-38.44837281
11	2017	181.040496	219.49	-38.44837281
12	2018	181.040496	228.27	-47.22792756
13	2019	181.040496	228.27	-47.22792756
14	2020	181.040496	228.27	-47.22792756
15	2021	181.040496	228.27	-47.22792756
16	2022	181.040496	228.27	-47.22792756
17	2023	181.040496	228.27	-47.22792756
18	2024	181.040496	228.27	-47.22792756
19	2025	181.040496	228.27	-47.22792756
20	2026	181.040496	228.27	-47.22792756
21	2027	181.040496	228.27	-47.22792756
22	2028	181.040496	228.27	-47.22792756
			Total	-1049.308671

APPENDIX H. Fuel Cost Calculations

Table H.1 Fuel Cost Calculations on Section 1

Year	AADT	Light Vehicles	Heavy Vehicles	Speed LTV	Speed HTV	Delay	Fuel Consumption (LTV)	Fuel Consumption (HTV)	Fuel Cost (LTV)	Fuel Cost (HTV)	Total Saving	Total Saving	Saving
				Miles/ Hr	Miles/ Hr	Mins	Gallons/ minutes	Gallons/ minutes	PKR/ LTR	PKR/ LTR		Million PKR	2007 PV
2007	20308	14504	5804	62.14	55.93	1	0.0395	0.0325	45906230.0326	15114629.5235	61020859.556	61.021	61.021
2008	22147	16040	6107	62.14	55.93	1	0.0395	0.0325	50767783.3510	15903694.4349	66671477.7859	66.672	64.11
2009	22206	16485	5721	62.14	55.93	1	0.0395	0.0325	52176241.1809	14898483.0296	67074724.2105	67.0747	62.014
2010	24114	18087	6027	62.14	55.93	1	0.0395	0.0325	57246689.3684	15695360.4649	72942049.8333	72.9420	64.845
2011	24267	18849	5418	62.14	55.93	1	0.0395	0.0325	59658475.5850	14109418.1183	73767893.7032	73.7679	63.057
2012	23981	18298	5683	62.14	55.93	1	0.0395	0.0325	57914519.9350	14799524.3939	72714044.3288	72.7140	59.765
2013	23026	17248	5778	62.14	55.93	1	0.0395	0.0325	54591192.4712	15046920.9833	69638113.4545	69.6381	55.036
2014	21594	15985	5609	62.14	55.93	1	0.0395	0.0325	50593704.2934	14606815.4716	65200519.7650	65.2005	49.547
2015	22458	16624	5833	62.14	55.93	1	0.0395	0.0325	52617452.4651	15191088.0905	67808540.5556	67.8085	49.547
2016	23356	17289	6067	62.14	55.93	1	0.0395	0.0325	54722150.5637	15798731.6141	70520882.1778	70.5209	49.547
2017	24290	17981	6309	62.14	55.93	1	0.0395	0.0325	56911036.5863	16430680.8787	73341717.4649	73.3417	49.547
2018	25262	18700	6562	62.14	55.93	1	0.0395	0.0325	59187478.0497	17087908.1138	76275386.1635	76.2754	49.547
2019	26272	19448	6824	62.14	55.93	1	0.0395	0.0325	61554977.1717	17771424.4384	79326401.6101	79.3264	49.547
2020	27323	20226	7097	62.14	55.93	1	0.0395	0.0325	64017176.2586	18482281.4159	82499457.6745	82.4995	49.547
2021	28416	21035	7381	62.14	55.93	1	0.0395	0.0325	66577863.3089	19221572.6725	85799435.9815	85.7994	49.547
2022	29553	21877	7676	62.14	55.93	1	0.0395	0.0325	69240977.8413	19990435.5794	89231413.4207	89.2314	49.547
2023	30735	22752	7983	62.14	55.93	1	0.0395	0.0325	72010616.9549	20790053.0026	92800669.9575	92.8007	49.547
2024	31964	23662	8303	62.14	55.93	1	0.0395	0.0325	74891041.6331	21621655.1227	96512696.7558	96.5127	49.547
2025	33243	24608	8635	62.14	55.93	1	0.0395	0.0325	77886683.2984	22486521.3276	100373204.6261	100.3732	49.547
2026	34573	25593	8980	62.14	55.93	1	0.0395	0.0325	81002150.6304	23385982.1807	104388132.8111	104.3881	49.547
2027	35956	26616	9339	62.14	55.93	1	0.0395	0.0325	84242236.6556	24321421.4680	108563658.1236	108.5637	49.547
2028	37394	27681	9713	62.14	55.93	1	0.0395	0.0325	87611926.1218	25294278.3267	112906204.4485	112.9062	49.547
												Total Cost	**1173.1**

Table H.2 Fuel Cost Calculations on Section 2

Year	AADT	Light Vehicles	Heavy Vehicles	Speed LTV	Speed (HTV)	Delay	Fuel Consumption(LTV)	Fuel Consumption(HTV)	Fuel Cost (LTV)	Fuel Cost (HTV)	Total Cost	Total Cost	Cost
				Miles/ Hr	Miles/ Hr	Mins	Gallons/ minutes	Gallons/ minutes	PKR/ LTR	PKR/ LTR		Million PKR	2007 PV
2007	10803	7203	3600	62.14	55.93	1	0.0395	0.0325	22798026.4013	9375028.6500	32173055.051	32.17305505	32.1731
2008	12177	8047	4130	62.14	55.93	1	0.0395	0.0325	25469348.6674	10755241.201	36224589.868	36.22458987	34.8313
2009	11346	7874	3472	62.14	55.93	1	0.0395	0.0325	24921790.9044	9041694.2980	33963485.202	33.9634852	31.40115126
2010	13395	9638	3757	62.14	55.93	1	0.0395	0.0325	30504981.0435	9783884.0661	40288865.109	40.28886511	35.81665438
2011	14765	11280	3485	62.14	55.93	1	0.0395	0.0325	35702032.1820	9075548.5681	44777580.750	44.77758075	38.27606369
2012	15282	11677	3605	62.14	55.93	1	0.0395	0.0325	36958566.4707	9388049.5231	46346615.993	46.34661599	38.09353999
2013	14790	11145	3645	62.14	55.93	1	0.0395	0.0325	35274747.2224	9492216.5081	44766963.730	44.76696373	35.37998171
2014	14170	10496	3674	62.14	55.93	1	0.0395	0.0325	33220614.3424	9567737.5723	42788351.914	42.78835191	32.51563082
2015	14737	10916	3821	62.14	55.93	1	0.0395	0.0325	34549438.9161	9950447.0751	44499885.991	44.49988599	32.51563082
2016	15326	11352	3974	62.14	55.93	1	0.0395	0.0325	35931416.4727	10348464.958	46279881.430	46.27988143	32.51563082
2017	15939	11807	4133	62.14	55.93	1	0.0395	0.0325	37368673.1316	10762403.556	48131076.688	48.13107669	32.51563082
2018	16577	12279	4298	62.14	55.93	1	0.0395	0.0325	38863420.0569	11192899.698	50056319.755	50.05631976	32.51563082
2019	17240	12770	4470	62.14	55.93	1	0.0395	0.0325	40417956.8592	11640615.686	52058572.545	52.05857255	32.51563082
2020	17930	13281	4649	62.14	55.93	1	0.0395	0.0325	42034675.1336	12106240.314	54140915.447	54.14091545	32.51563082
2021	18647	13812	4835	62.14	55.93	1	0.0395	0.0325	43716062.1389	12590489.926	56306552.065	56.30655207	32.51563082
2022	19393	14365	5028	62.14	55.93	1	0.0395	0.0325	45464704.6245	13094109.523	58558814.148	58.55881415	32.51563082
2023	20168	14939	5229	62.14	55.93	1	0.0395	0.0325	47283292.8094	13617873.904	60901166.714	60.90116671	32.51563082
2024	20975	15537	5438	62.14	55.93	1	0.0395	0.0325	49174624.5218	14162588.860	63337213.382	63.33721338	32.51563082
2025	21814	16158	5656	62.14	55.93	1	0.0395	0.0325	51141609.5027	14729092.415	65870701.918	65.87070192	32.51563082
2026	22687	16804	5882	62.14	55.93	1	0.0395	0.0325	53187273.8828	15318256.112	68505529.994	68.50552999	32.51563082
2027	23594	17477	6117	62.14	55.93	1	0.0395	0.0325	55314764.8381	15930986.356	71245751.194	71.24575119	32.51563082
2028	24538	18176	6362	62.14	55.93	1	0.0395	0.0325	57527355.4316	16568225.810	74095581.242	74.09558124	32.51563082
												Total Cost	**733.7062448**

Table H.3 Fuel Cost Calculations on Section 3

Year	AADT	Light Vehicle	Heavy Vehicle	Speed (LTV)	Speed (HTV)	Delay	Fuel Consumption (LTV)	Fuel Consumption (HTV)	Fuel Cost (LTV)	Fuel Cost (HTV)	Total Cost	Total Cost	Cost
				Miles/ Hr	Miles/ Hr	Mins	Gallons/ minutes	Gallons/ minutes	PKR/ LTR	PKR/ LTR		Million PKR	2007 PV
2007	8479	5558	2921	62.14	55.93	1	0.0395	0.0325	17591480.0415	7606794.0796	25198274.1	25.19827412	25.1982741
2008	9998	6644	3354	62.14	55.93	1	0.0395	0.0325	21028750.1611	8734401.6923	29763151.8	29.76315185	28.6184152
2009	10519	7357	3162	62.14	55.93	1	0.0395	0.0325	23285447.7627	8234400.1643	31519847.9	31.51984793	29.1418712
2010	11507	8388	3119	62.14	55.93	1	0.0395	0.0325	26548638.8247	8122420.6554	34671059.4	34.67105948	30.8224456
2011	11997	9008	2989	62.14	55.93	1	0.0395	0.0325	28510984.5652	7783877.9541	36294862.5	36.29486252	31.0250005
2012	12599	9628	2971	62.14	55.93	1	0.0395	0.0325	30473330.3057	7737002.8109	38210333.1	38.21033312	31.4061085
2013	12438	2370	10068	62.14	55.93	1	0.0395	0.0325	7501224.8468	26218830.1245	33720054.9	33.72005497	26.6494492
2014	12138	9015	3123	62.14	55.93	1	0.0395	0.0325	28533140.0816	8132837.3539	36665977.4	36.66597744	27.8631293
2015	12624	9376	3248	62.14	55.93	1	0.0395	0.0325	29674465.6849	8458150.8480	38132616.5	38.13261653	27.8631293
2016	13128	9751	3378	62.14	55.93	1	0.0395	0.0325	30861444.3123	8796476.8820	39657921.	39.65792119	27.8631293
2017	13654	10141	3513	62.14	55.93	1	0.0395	0.0325	32095902.0848	9148335.9572	41244238.0	41.24423804	27.8631293
2018	14200	10546	3653	62.14	55.93	1	0.0395	0.0325	33379738.1682	9514269.3955	42894007.	42.89400756	27.8631293
2019	14768	10968	3800	62.14	55.93	1	0.0395	0.0325	34714927.6949	9894840.1713	44609767.	44.60976787	27.8631293
2020	15358	11407	3952	62.14	55.93	1	0.0395	0.0325	36103524.8027	10290633.7782	46394158.6	46.39415858	27.8631293
2021	15973	11863	4110	62.14	55.93	1	0.0395	0.0325	37547665.7948	10702259.1293	48249924.9	48.24992492	27.8631293
2022	16612	12338	4274	62.14	55.93	1	0.0395	0.0325	39049572.4266	11130349.4945	50179921.9	50.17992192	27.8631293
2023	17276	12831	4445	62.14	55.93	1	0.0395	0.0325	40611555.3237	11575563.4743	52187118.8	52.1871188	27.8631293
2024	17967	13344	4623	62.14	55.93	1	0.0395	0.0325	42236017.5366	12038586.0132	54274603.5	54.27460355	27.8631293
2025	18686	13878	4808	62.14	55.93	1	0.0395	0.0325	43925458.2381	12520129.4538	56445587.7	56.44558769	27.8631293
2026	19433	14433	5000	62.14	55.93	1	0.0395	0.0325	45682476.5676	13020934.6319	58703411.2	58.7034112	27.8631293
2027	20211	15011	5200	62.14	55.93	1	0.0395	0.0325	47509775.6303	13541772.0172	61051547.6	61.05154765	27.8631293
2028	21019	15611	5408	62.14	55.93	1	0.0395	0.0325	49410166.6555	14083442.8979	63493609.	63.49360955	27.8631293
												Total Cost	**620.8**

Table H.4 Fuel Cost Calculations on Section 4

Year	AADT	Light Vehicle	Heavy Vehicle	Speed (LTV)	Speed (HTV)	Delay	Fuel Consumption (LTV)	Fuel Consumption (HTV)	Fuel Cost (LTV)	Fuel Cost (HTV)	Total Cost	Total Cost	Cost
				Miles/ Hr	Miles/ Hr	Mins	Gallons/ minutes	Gallons/ minutes	PKR/ LTR	PKR/ LTR		Million PKR	2007 PV
2007	7700	5093	2607	62.14	55.93	1	0.0395	0.0325	16119720.7361	6789083.2474	22908803.983	22.90880398	22.908
2008	9383	6194	3189	62.14	55.93	1	0.0395	0.0325	19604466.9624	8304712.8791	27909179.841	27.90917984	26.8357
2009	9734	6870	2864	62.14	55.93	1	0.0395	0.0325	21744056.8343	7458356.1260	29202412.960	29.20241296	26.9992
2010	10688	7926	2762	62.14	55.93	1	0.0395	0.0325	25086374.7407	7192730.3143	32279105.054	32.27910505	28.6960
2011	11329	8666	2663	62.14	55.93	1	0.0395	0.0325	27428529.3342	6934917.0264	34363446.360	34.36344636	29.3740
2012	12649	9840	2809	62.14	55.93	1	0.0395	0.0325	31144325.9460	7315126.5216	38459452.467	38.45945247	31.6108
2013	12462	9535	2927	62.14	55.93	1	0.0395	0.0325	30178978.4446	7622419.1274	37801397.572	37.80139757	29.8749
2014	12110	9126	2984	62.14	55.93	1	0.0395	0.0325	28884463.2707	7770857.0810	36655320.351	36.65532035	27.8550
2015	12594	9491	3103	62.14	55.93	1	0.0395	0.0325	30039841.8015	8081691.3642	38121533.165	38.12153317	27.8550
2016	13098	9871	3227	62.14	55.93	1	0.0395	0.0325	31241435.4735	8404959.0188	39646394.492	39.64639449	27.8550
2017	13622	10266	3357	62.14	55.93	1	0.0395	0.0325	32491092.8925	8741157.3796	41232250.272	41.23225027	27.8550
2018	14167	10676	3491	62.14	55.93	1	0.0395	0.0325	33790736.6082	9090803.6747	42881540.282	42.88154028	27.8550
2019	14734	11103	3630	62.14	55.93	1	0.0395	0.0325	35142366.0725	9454435.8217	44596801.894	44.59680189	27.8550
2020	15323	11547	3776	62.14	55.93	1	0.0395	0.0325	36548060.7154	9832613.2546	46380673.970	46.38067397	27.8550
2021	15936	12009	3927	62.14	55.93	1	0.0395	0.0325	38009983.1440	10225917.784	48235900.928	48.23590093	27.8550
2022	16573	12490	4084	62.14	55.93	1	0.0395	0.0325	39530382.4698	10634954.496	50165336.966	50.16533697	27.8550
2023	17236	12989	4247	62.14	55.93	1	0.0395	0.0325	41111597.7686	11060352.676	52171950.444	52.17195044	27.8550
2024	17926	13509	4417	62.14	55.93	1	0.0395	0.0325	42756061.6793	11502766.783	54258828.462	54.25882846	27.8550
2025	18643	14049	4594	62.14	55.93	1	0.0395	0.0325	44466304.1465	11962877.454	56429181.600	56.4291816	27.8550
2026	19389	14611	4777	62.14	55.93	1	0.0395	0.0325	46244956.3123	12441392.552	58686348.864	58.68634886	27.8550
2027	20164	15195	4969	62.14	55.93	1	0.0395	0.0325	48094754.5648	12939048.254	61033802.819	61.03380282	27.8550
2028	20971	15803	5167	62.14	55.93	1	0.0395	0.0325	50018544.7474	13456610.184	63475154.932	63.47515493	27.8550
												Total Cost	**614.126**

Table H.5 Fuel Cost Calculations on Section 5

Year	AADT	Light Vehicle	Heavy Vehicle	Speed (LTV)	Speed (HTV)	Delay	Fuel Consumption (LTV)	Fuel Consumption (HTV)	Fuel Cost (LTV)	Fuel Cost (HTV)	Total Cost	Total Cost	Cost
				Miles/ Hr	Miles/ Hr	Mins	Gallons/ minutes	Gallons/ minutes	PKR/ LTR	PKR/ LTR		Million PKR	2007 PV
2007	10529	7689	2840	62.14	55.93	1	0.0395	0.0325	24336252.256	7395855.9350	31732108.2	31.73210819	31.7321081
2008	12716	9483	3233	62.14	55.93	1	0.0395	0.0325	30014394.608	8419296.5626	38433691.2	38.43369117	36.9554722
2009	12807	9754	3053	62.14	55.93	1	0.0395	0.0325	30872129.601	7950545.1301	38822674.7	38.82267473	35.8937451
2010	12402	9856	2546	62.14	55.93	1	0.0395	0.0325	31194967.126	6630228.5953	37825195.7	37.82519572	33.6264612
2011	13629	11200	2429	62.14	55.93	1	0.0395	0.0325	35448826.280	6325540.1641	41774366.4	41.77436644	35.7089035
2012	14869	12295	2574	62.14	55.93	1	0.0395	0.0325	38914582.063	6703145.4848	45617727.5	45.61772755	37.4944468
2013	14317	11648	2669	62.14	55.93	1	0.0395	0.0325	36866779.331	6950542.0741	43817321.4	43.81732141	34.6294655
2014	12110	12010	100	62.14	55.93	1	0.0395	0.0325	38012536.037	260417.4625	38272953.5	38.2729535	29.0842991
2015	12594	12490	104	62.14	55.93	1	0.0395	0.0325	39533037.479	270834.1610	39803871.6	39.80387164	29.0842991
2016	13098	12990	108	62.14	55.93	1	0.0395	0.0325	41114358.978	281667.5274	41396026.5	41.39602651	29.0842991
2017	13622	13510	112	62.14	55.93	1	0.0395	0.0325	42758933.337	292934.2285	43051867.6	43.05186757	29.0842991
2018	14167	14050	117	62.14	55.93	1	0.0395	0.0325	44469290.671	304651.5977	44773942.3	44.77394227	29.0842991
2019	14734	14612	122	62.14	55.93	1	0.0395	0.0325	46248062.298	316837.6616	46564899.9	46.56489996	29.0842991
2020	15323	15196	127	62.14	55.93	1	0.0395	0.0325	48097984.789	329511.1680	48427495.9	48.42749596	29.0842991
2021	15936	15804	132	62.14	55.93	1	0.0395	0.0325	50021904.181	342691.6148	50364595.8	50.365	29.0842991
2022	16573	16437	137	62.14	55.93	1	0.0395	0.0325	52022780.348	356399.2794	52379179.6	52.37917963	29.0842991
2023	17236	17094	142	62.14	55.93	1	0.0395	0.0325	54103691.56	370655.2505	54474346.8	54.47434681	29.0842991
2024	17926	17778	148	62.14	55.93	1	0.0395	0.0325	56267839.225	385481.4606	56653320.7	56.65332069	29.0842991
2025	18643	18489	154	62.14	55.93	1	0.0395	0.0325	58518552.794	400900.7190	58919453.5	58.91945351	29.0842991
2026	19389	19228	160	62.14	55.93	1	0.0395	0.0325	60859294.91	416936.7477	61276231.7	61.276232	29.084299
2027	20164	19998	167	62.14	55.93	1	0.0395	0.0325	63293666.70	433614.2176	63727280.9	63.727280	29.0842991
2028	20971	20797	173	62.14	55.93	1	0.0395	0.0325	65825413.370	450958.7864	66276372.2	66.28	29.0842991
												Total Cost	**682.3**