BE CIVIL ENGINEERING

PROJECT REPORT

PERFORMANCE EVALUATION OF AN AT GRADE SIGNALIZED URBAN INTERSECTION USING SYNCHRO/SIMTRAFFIC

Project submitted in partial fulfillment of the requirements for the degree of

BE Civil Engineering

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This to certify that the

BE Civil Engineering Project entitled

PERFORMANCE EVALUATION OF AN AT GRADE SIGNALIZED URBAN INTERSECTION USING SYNCHRO/SIMTRAFFIC AND ITS IMPROVEMENT

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Has been accepted towards the partial fulfilment of the requirements for

BE Civil Engineering Degree

Dr. Muhammad Irfan, Ph. D

Syndicate Advisor

Dedication

Special dedication to our parents, teachers and well wishers

For all the support, encouragement and belief in us. Thank you so much.

ACKNOWLEDGEMENT

First of all thanks to Almighty Allah for his blessings, who enabled me to complete my UG project. There are number of people without whom this might not have been written, and to whom I am greatly obliged.

Last but not least, my deepest gratitude goes to my beloved parents particularly my father Javed Hussain (late) who was always a symbol of encouragement and inspiration to me throughout my life. Special thanks to my Mother, sisters and brother for their never-ending love and prayers. Last but not the least my uncle Amjad Ali who always kept supporting me. To those who in some way contributed in this research, your kindness means a lot to us. Thank you very much.

And in the end, I want to thank my advisor Dr. Muhammad Irfan for his guidance and directing us towards our goal in a friendly way.

Faisal Raza (Syndicate Leader)

CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Traffic Congestion and delays on an at-grade urban signalized intersection are a major problem in traffic engineering. Estimation of average travel and running speed on urban signalized intersections from transportation models are inadequate to meet the many demands being placed on them. Urban Signalized intersections have substantial positive economic and social impacts to road users with reducing the delays. The advantages of signalized intersection include the orderly movement of traffic, un-interrupted heavy flows for minor traffic movements, provides gap for minor traffic movements, promotes driver confidence, and reduces certain types of major and minor crashes.

This study is carried out to evaluate the delays on existing Koral Chowk, Islamabad, a 4-leg signalized intersection. The field data was carried out on three different days of a week Tuesday, Friday and Sunday. Here we count the three hours traffic and turning movements' data which is also the peak hour of that day. After the data collection we have to find the peak hour of that day. As we get the peak hour of that particular day we have three peak hours one for Tuesday, one for Friday and one for Sunday. The one which is maximum of these three is the peak hour of that week. Once we got the peak hour of that week we have to find the PHF. Now we have the peak hour turning movement count along with the PHF. To optimize the existing traffic signal we requires the flow of current traffic and the turning movements data, optimization models experience and also the knowledge of signal timing and their operation. It includes the determination and optimization of control delay, approach delays, traffic congestion, capacity analysis, saturation flow rate, queue lengths, v/c ratio, level of service and intersection capacity utilization and its level of service.

The analysis of results we obtained was carried out by using software synchro/simtraffic version 8.0. The synchro/simtraffic is a powerful analysis software which not only give us the existing capacity, saturation flow rate, level of service of all approaches and for whole intersection, intersection capacity utilization and its level of service, uniform delay, incremental delay and control delay and v/c ratio of all approaches, emissions produced and much more that are required for performance evaluation of at-grade signalized intersection.

Chapter 1

INTRODUCTION

1.1 Background

Traffic Congestion and delays on an at-grade urban signalized intersection are a major problem in traffic engineering. Estimation of average travel and running speed on urban signalized intersections from transportation models are inadequate to meet the many demands being placed on them. Link travel time determines the choice of route and if we talk about the long term, it also determines the number of vehicle trips. Similarly, the efficient traffic signals timing depends on the accurate estimation of the time it takes to travel between them. Signalized arterials comprise a complex state in between idealized traffic streams and intersections.

Urban Signalized intersections have substantial positive economic impact to road users with reducing the control delays. Some of the other advantages of signalized intersections includes the orderly movement of traffic, un-interrupted heavy flows for minor traffic movements, provides gap for minor traffic movements, promotes driver confidence, and reduces certain types of major and minor crashes.

This study is carried out to evaluate the delays on existing Koral Chowk, Islamabad, a 4-leg signalized intersection. It includes the determination and optimization of control delay, approach delays, traffic congestion, capacity analysis, saturation flow rate, queue lengths, v/c ratio, level of service and intersection capacity utilization and its level of service. Options are available to optimize the existing signalized intersection. Micro simulation software Synchro/simTraffic will be used to optimize existing urban signalized intersection. The performance of the signalized intersection in existing conditions and after optimization is being compared using the results of software Synchro/simTraffic under a microscopic simulation environment. The research will further help us in determining the performance evaluation of urban signalized intersection in other areas. It also helps us for making a decision for grade separation or not in a long run at existing 4-leg urban signalized intersection.

1.2 Research Objectives

Measuring control delays in the field accurately is important for designing and operating traffic signals timings. As a performance measure, control delay plays a critical and important role in evaluating levels of service and intersection capacity utilization and its level of service at signalized intersections. Delay at signalized intersections is defined and used in many different ways. Our objective is to focus on control delays, uniform delays, and incremental delays. These delays on signalized intersection will improve by improving the traffic condition on signalized intersection, reducing delays and reducing number of crashes that must be a major concern. The specific objectives of this research can be summarized as the following points:

- To determine the capacity of urban signalized intersection on existing conditions.
- To determine control delays of all approaches and for whole intersection, before and after optimization, this is important in determining the level of services of all approaches.
- To determine level of service of all approaches and for whole intersection before and after optimization.
- To study the economic and social impacts i.e. emissions due to traffic at Koral Chowk.
- Recommend new solutions regarding the problems.

1.3 Scope of the Work

To accomplish the above-mentioned research objectives, a comprehensive research plan was prepared and the following research tasks were outlined:

- Literature review of the previous research finding on parameters like control delays, saturation flow rate, capacity and v/c ratio, level of service and intersection capacity utilization affecting performance of at-grade urban signalized intersection.
- On field data collection and collation so as to determine the peak hour volume counts and peak hour factor.

- Analysis with Synchro/simTraffic and to get the results before and after optimization.
- Comparison of the results obtained from Synchro/simTraffic which will further help for future short term and long term solutions.

1.4 Organization of the Report

This research is organized into six chapters as shown in figure below.

- Chapter 1 includes a brief introduction of urban signalized intersection, research objectives including the importance of determining control delay and its impact on level of service and capacity analysis of signalized intersection and the scope of the research.
- Chapter 2 includes a literature review on findings of the previous studies and factor that are used by researchers regarding the performance evaluation at-grade urban signalized intersection. In addition to it describes the at-grade urban signalized intersection, traffic congestion and homogeneous and heterogeneous flow of traffic.
- Chapter 3 explains the selection of site and collection of data turning movement counts (using Jamar traffic data collector) used in this research, determination of peak hour volume counts, peak hour factor and input parameters (Geometric condition, Traffic condition and Signalization condition) and analysis according to HCM 2000 method.
- Chapter 4 presents the data entry procedure in Synchro/simTraffic their analysis. The analysis include the capacity analysis, delay analysis, determining the level of service and intersection capacity utilization and its level of services before and after optimization and results comparison.
- Chapter 5 presents the solution and the economic and social impacts of Koral Chowk before and after improvement for years 2015 and 2020.
- Chapter 6 is concerned with the conclusions. Conclusions are drawn from research findings.

The test results obtained and analysis reports generated by Synchro/simTraffic version 8.0 software can be found in the appendixes.

CHAPTER 1 "INTRODUCTION"

- BACKGROUND
- RESEARCH OBJECTIVES
- SCOPE OF THE WORK
- ORGANIZATION OF THE WORK

CHAPTER 2 "LITERATURE REVIEW"

- INTRODUCTION
- AT GRADE URBAN SIGNALIZED INTERSECTION
- TRAFFIC CONGESTIONS ON URBAN SIGNALISED INTERSECTIONS
- TRAFFIC FLOW ON URBAN SIGNALISED INTERSECTIONS
- ANALYSIS OF AT-GRADE URBAN INTERSECTIONS
- WHAT IS SYNCHRO/SIMTRAFFIC

CHAPTER 3 "RESEARCH METHODOLOGY"

- INTRODUCTION
- METHOD OF ANALYSIS OF SIGNALISED INTERSECTIONS
- DATA COLLECTION AND COLLATION
- INPUT PARAMETERS
- ANALYSIS
- SUMMARY

CHAPTER 4 "DATA ANALYSIS, RESULTS AND CONCLUSIONS"

- INTRODUCTION
- DATA ENTRY
- EXISTING RESULTS BEFORE OPTIMIZATION
- RESULTS AFTER OPTIMIZATION
- RESULTS COMPARISON
- COMPARISON OF SIMULATION RESULTS BEFORE AND AFTER OPTIMIZATION
- SYNCHRO RESULTS AFTER 5 YEARS
- SUMMARY

CHAPTER 5 RECOMMENDED SOLUTIONS AND ENVIRONMENTAL IMPACT ASSESSMENT

- GENERAL
- PROPOSED SOLUTION
- PROJECTION TILL 2020
- COMPARISON OF RESULTS BEFORE AND AFTER IMPROVEMENT
- ENVIRONMENTAL IMPACT ANALYSIS
- ECONOMIC IMPACT ANALYSIS
- SOCIAL IMPACT ANALYSIS
- SUMMARY

CHAPTER 6 CONCLUSIONS

- GENERAL
- CONCLUSIONS
- FUTURE RECOMMENDATIONS

Figure 1.1 Organization of the Report

Chapter 2

LITRATURE REVIEW

2.1 Introduction

This chapter is a review of the literature and theory about the performance of existing urban signalized intersection. The previous research on urban signalized intersection has shown that existing traffic signals is one of the most important tasks that an agency can do to improve traffic flow. Traffic flow has been improved up to 26 percent in the recent time.

To optimize the existing traffic signal we requires the flow of current traffic and the turning movements data, optimization models experience and also the knowledge of signal timing and their operation. To set the new signal timing for the efficient movement of traffic is a time consuming task and requires lots of budgetary expenses. So, this process includes following steps:

- To organize existing information we have,
- Collection of new traffic flow data on existing urban signalized intersection,
- Optimization of signal timing using the software Synchro/SimTraffic,
- Selection of optimum signal timing and there settings,
- Installation of new signal timing on an urban signalized intersection,
- If the level of service is still F after optimization, the solution is of grade separation.

Practitioners in the field have developed practical and cost-effective means to shorten the tasks, and also generate traffic signal timing plans that can easily approximate the effectiveness of developed traffic signal timing using the modelling process. These plans are referred as “near-optimum” plans. But we can’t expect the same quality of traffic signal timing output from a shorten method as we obtained from the formal, expensive process. But, when we faced with a lack of resources such that traffic signal timing by conventional means is not possible, these shorten methods should be considered.

Our work examines the informal traffic signal timing process and defines the method that can be used to optimize traffic signal timing. The efforts made places a primary emphasis on updating the signal timing on an urban signalized intersection. In other words we can say that, the efforts made are used that how to develop signal timing plans and also updated the efficiently of signalized intersection and what are requirements of grade separation.

2.2 At-Grade Urban Signalized Intersection

2.2.1 Introduction

- Intersections are a major source of vehicle delay (as vehicles yield to avoid conflicts with other vehicles) and crashes.
- Most roadway intersections are not signalized due to low traffic volumes and adequate sight distances.
- Conflicting traffic movements, make roadway intersections a source of great concern to traffic engineers.
- At some point, crash frequency/severity (and other factors) and traffic volumes reach levels that warrant the installation of a traffic signal.

An intersection is a location where two or more roads carrying traffic streams in different directions cross. At such a location, obviously, different traffic streams compete with one another for the use of the common space or the intersection. If left on its own the flow at an intersection will always be chaotic; the safety and efficiency at such locations will be low. Hence, various strategies are used to control the flow of traffic at an intersection in order to improve the safety and efficiency of traffic flow.

Figure 2.1 At-Grade Urban Signalized Intersection

2.2.2 Advantages

- Provisions for side-street vehicles to enter the traffic stream
- Potential reduction of some types of crashes (particularly angle crashes)
- Possible improvements in capacity
- Provisions for pedestrians to cross the street
- Possible reductions in delay
- Provisions for the progressive flow of traffic in a signal-system corridor.

2.2.3 Disadvantages

- Increasing vehicle delay,
- Increasing vehicle crashes (particularly rear-end crashes),
- Causing a disruption to traffic progression (adversely impacting the through movement of traffic), and
- Encouraging the use of routes not intended for through traffic (such as routes through residential neighborhoods).

At an at-grade urban signalized intersection, the common space is periodically given to certain flows while other conflicting streams are barred from entry at that time. In a manner of speaking the common space is time-shared among the various flows. Although, there are various kinds of time sharing strategies like pre-timed, partially actuated, and fully actuated signalizations.

- Pre-timed signal are those signals whose timing (green time, cycle length, and so on) is fixed over specified time periods and does not change in response to changes in traffic flow at the intersection. No vehicle detection is necessary with this mode of operation.
- Partially Actuated are those signals whose timing (green time, cycle length, and so on) is affected when vehicles are detected (by video or pavement-embedded inductance loop detectors) on some, but not all, approaches.
- Fully-Actuated are those signals whose timing (green time, cycle length, and so on) is completely influenced by the traffic volumes with detectors on all of the approaches. Fully actuated signals are most commonly used at intersections of two major streets and where substantial variations exist in all approach traffic volumes over the course of a day.

Here we are talking about the pre-timed signalization and its effect on flow is studied. The other strategies, where the time sharing mechanism changes more frequently than in the pre-timed strategy are not studied here as the basic traffic flow analysis process is the same as that of the pre-timed strategy.

In the pre-timed signalization, the time sharing between the different conflicting flows occurs according to a pre-defined strategy which repeats at a fixed interval referred to as the cycle length. During the cycle length, the time for which a particular stream can utilize the intersection is referred to as the green time for that stream or movement; the time during which a particular movement cannot utilize the intersection is referred to as the red time for that movement. Invariably during the change over from green to red an amber (yellow) signal is shown to warn the driver that a red signal is impending. During the amber (yellow) time for a movement the vehicles of that movement can use the intersection. Of course the sum of green, amber (yellow) and red times for a particular movement is equal to the cycle time.

2.3 Traffic Congestions on Urban Intersections

Traffic congestion is a condition that occurs as use increases, and is characterized by slower speeds, delays, longer trip times, and increased vehicular queuing. The most common example is the physical use of signalized intersection by vehicles. When traffic demand is great enough that the interaction between vehicles slows the speed of the traffic stream on signalized intersection, this results in some congestion. As demand approaches the capacity, extreme traffic congestion sets in. When vehicles are fully stopped for periods of time, this is colloquially known as a traffic jam or traffic snarl-up on signalized intersection.

2.3.1 Causes of Traffic Congestion

Recurring

- Insufficient capacity
- Unrestrained demand
- Ineffective management of capacity (e.g. poor signal timing)

Non-Recurring

- Incidents
- Work zones
- Weather events
- Special events
- Emergencies (e.g. hurricanes)

Figure 2.2 Traffic Congestion on Urban Signalized Intersection

2.4 Traffic Flow on Urban Signalized Intersection

2.4.1 Homogenous and Heterogeneous Traffic Flow

Intersections are very important nodal points in a network of transportation and the efficiency of their operation have a great influence on the entire road network. Homogeneous traffic consists of a stream of identical vehicles Fig.2.3. But in heterogeneous traffic conditions, there is a mix-up of vehicles and they do not follow the ordered queue and lane discipline Fig.2.4. Heterogeneous traffic condition generally operates differently as compared to homogeneous traffic condition due to wide variations in performance characteristics of vehicles and there operations. Heterogeneous traffic also includes cars (including jeeps and vans), buses, motorized two wheelers (MTW), light commercial vehicles, auto-rickshaws (three wheeled motorized vehicles). (LCV) and bicycles and trucks which share the common road space without any physical segregation. At these signalized urban intersections, generally smaller vehicles use the lateral gaps between larger vehicles to accommodate the approach space. Due to vehicle interactions, heterogeneity & complex manoeuvres, it is very difficult to develop an analytical model for studying such traffic flow characteristics. So we can say that, simulation is an effective tool for studying heterogeneous traffic.

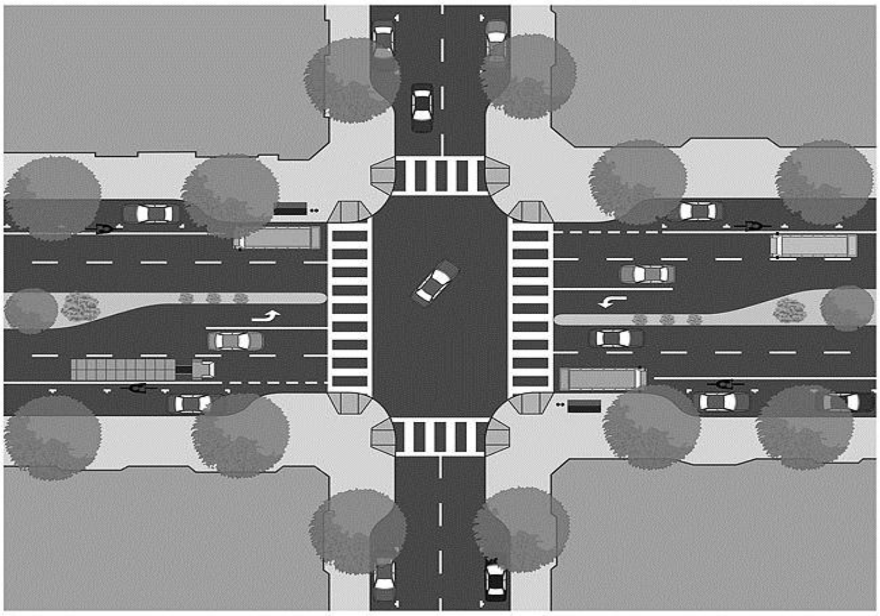

Figure 2.3 Homogeneous Traffic Flow on Urban Signalized Intersection

Figure 2.4 Heterogeneous Traffic Flow on Urban Signalized Intersection

Various investigations on urban signalized intersections have been already carried out under homogeneous traffic flow to determine queue length, platoon dispersion, queue dissipation, delays, driver and vehicular traffic etc. These studies include studies by Laoufi *et al.* (2004), Mousa (2003), Kim and Benekohal (2005), Clement *et al.* (2004), Addison and Low (1996), Olszewski (1993), Zuylen and Taale (2001), Lin and Cooke (1986). The capacity of signalized urban intersection approach is studied by Tian and Wu (2005) also estimate with a short right turn lane based on the length of the short lane, proportion of through and right-turn vehicles and cycle length. The effects of right-turn volume, auxiliary lane length and through/right-turn lane group delay on the level of their utilization was studied by Tarawneh, M. S. and Tarawneh, T. M. (2002). Mathematical model to estimate the capacity for using exclusive double left turn lanes was built by Hurley (1998). Left turn adjustment factors for double left turn lanes in medium size cities was developed by Spring and Thomas (1999). Janson and Buchholz (1998) worked out saturation flow and delay equations for both exclusive and shared lanes. Lin (1992) provides left-turn adjustment factors for shared permissive left turn lane and also estimates the capacities.

Only limited number of research on modelling heterogeneous traffic through urban signalized intersections has been done yet. Various simulation models for uncontrolled signalized intersection were designed by Agarwal *et al.* (1994), Rao and Rengaraju (1998), Popat *et al.* (1989) and Raghavachari *et al.* (1993). A simulation model was created by Marwah *et al.* (2006) for signalized intersection to estimate queue length and delay. The platoon dispersal pattern for heterogeneous traffic at an urban signalized intersection using a simulation model was done by Arasan and Kashani (2003). Hossain (2001) estimated saturation flow at urban signalized intersections based on turning proportion, road width and percentage of heavy and non-motorized vehicles using a micro-simulation modelling approach. The discharge characteristics of vehicles and vehicle characteristics at urban signalized intersections were analysed by Maini and Khan (2000). The effect of vehicle heterogeneity on urban signalized intersections and proposed a probabilistic approach to estimate saturation flow and delay was studied by Arasan and Jagadeesh (1995). The above mentioned studies highlight the importance of addressing traffic flow at urban signalized intersections, but still there is a need and further scope for studies on queue formation, queue density, queue accumulation and dissipation at and near urban signalized intersections areas. There is also a need of effective traffic regulation and control and to evolve and study appropriate traffic control and management measures and strategies for better utilization of transport infrastructure. Akgüngör, A. P. (2008a and 2008b) also analysed the delay parameter, which dependent on variable analysis periods at urban signalized intersections.

2.5 Analysis of At-Grade Signalized Urban Intersection

- Capacity Analysis
- Delay Analysis
- Level of Service (LOS)
- ICU Level of Service

2.5.1 Capacity Analysis

Here we discuss the basic methods used by all manuals to carry out their capacity analysis. There might be slight differences between all manuals that are being discussed here.

Capacity analysis is a set of procedures used to estimate the traffic carrying capacity of transportation facilities over a range of defined operational conditions. The procedures typically are being used to determine the level of service (LOS). They provide tools for the facility as well as the planning and design of future facilities.

Capacity analysis is carried out in order to design a signalized intersection as well as to carry out an operational analysis of an existing intersection. It is important because it helps us to determine the suitable size of an intersection (i.e. number of lanes for each approach), phasing and cycle time that is needed to be able to accommodate the traffic volume.

Chandra et al. (1994) described the capacity analysis for a signalized intersection as more complex than carrying out capacity analysis for a road. This is because the capacity of a road is only influenced by the parameters for the road itself, whereas the capacity for a signalized intersection differs according to the parameters of all the roads that make up the intersection. This includes the geometric parameters of the individual lanes, the area type, the turning movements and other related parameters. The factors that should be kept in mind to determine the signalized intersection capacity are:

- Traffic Volume
- Peak Hour Factor
- Saturation Flow Rate

For an existing intersection, the first thing that should be kept in mind is the traffic volume. This volume must be recorded directly at the signalized intersection itself. The volume from the point of observation should also not be limited by the capacity of the particular infrastructure. Thus, the traffic volume observation is not only restricted to intersections with adequate volumes but intersection with highly saturated flows can also be included.

From this traffic volume, the peak hour volume count and then peak-hour factor is determined. The percentages of left-turning and right-turning vehicles in a shared or exclusive lane also calculated thus left-turning and right-turning adjustment factors can be determined.

Next, the saturation flow rate of the intersection is determined. The saturation flow rate is the flow in vehicles per hour that can be accommodated by the lane group assuming that the green phase were displayed 100 percent of the time (i.e. g/C = 1.0) (TRB, 2000). Saturation flow rate is given by

$$s = \frac{3600}{h} \qquad (2.1)$$

Where,

s = saturation flow rate in veh/h,

h = saturation headway in s/veh, and

3600 = number of seconds per hour.

However, in order to determine the saturation flow rate, the ideal saturation flow for the intersection must first be determined. Table 2.1 displays the different values of ideal saturation flow rates for different countries.

Table 2.1 Values of ideal saturation flow rate for different countries

Country	**Manual**	**Ideal Saturation Flow Rate (pcu/hr/lane)**
Malaysia	Malaysian Highway Capacity Manual (2006)	1930
U.S	HCM 1985	1800
	HCM 1994	1900
	HCM 2000	1900
Australia	aaSIDRA	1950

The saturation flow rate is determined after the ideal saturation flow is to be taken from HCM 2000. The Equation used to determine saturation flow rate is as follows:

$$s = s_o * N * f_w * f_{HV} * f_g * f_p * f_{bb} * f_a * f_{LU} * f_{LT} * f_{RT} * f_{Lpb} * f_{Rpb} \qquad (2.2)$$

Where,

s = saturation flow rate for subject lane group, expressed as a total for all lanes in lane group (veh/h)

s_o = base saturation flow rate per lane (pc/h/ln)

N = number of lanes in lane group

f_w = adjustment factor for lane width

f_{HV} = adjustment factor for heavy vehicles in a traffic stream

f_g = adjustment factor for approach grade

f_p = adjustment factor for existence of parking lane & parking activity adjacent to lane group

f_{bb} = adjustment factor for blocking effect of all local buses that stop within the intersection area

f_a = adjustment factor for area type

f_{LU} = adjustment factor for lane utilization

f_{LT} = adjustment factor for left turns in a lane group

f_{RT} = adjustment factor for right turns in a lane group

f_{Lpb} = pedestrian adjustment factor for all left-turn movements

f_{Rpb} = pedestrian-bicycle adjustment factor for all right-turn movements

Signalized intersection capacity is then estimated as the product of the effective green split (Rouphail and Akcelik, 1996) and saturation flow rate. As the saturation flow rate is being calculated, the capacity can be determined using the basic equation used by all methods as shown below as:

$$\boldsymbol{c = \frac{S*g}{C}\ veh/hr} \qquad (2.3)$$

Where,

c = capacity of the approach (veh/hr)

g = average effective green time (sec)

C = average cycle time (sec)

S = saturation flow rate (veh/hr)

From the above value of capacity, we can now further determine the v/c ratio which will help us in determining the value for delay. When carrying out a capacity analysis and engineers will want to come up with a signalized intersection that has appropriate values of the measures of effectiveness (MOEs). Measures of effectiveness are indices of the effectiveness of signalized intersection and also helping to improve the traffic flow. Common bases of comparison include density, stops, congestion, delay, lane occupancy, and queue length.

2.5.2 Delay Analysis

At-Grade Urban Signalized intersections were developed in England in the early 20th century. With the passage of time the introduction of these controls to manoeuvre conflicting streams of passenger traffic and vehicular, researchers started to estimate delays due to these controls and also developing the optimum signal timings so as to minimize delay especially for pre-timed signals. Webster's equation is the 1st equation for measuring most delay developed in 1958 assuming practical distributions like Poisson (random) arrivals with uniform discharge headways.

Akcelik further developed the delay equation by utilizing the coordinate transformation technique to obtain a time-dependent equation that is applicable to signalized intersections. In USA delay, is defined by HCM 2000, is the additional travel time experienced by a driver, passenger or pedestrian. It includes the uniform delay, incremental delay and initial queue delay. The Highway Capacity Manual (HCM) delay equation is utilized in delay computations. The HCM 2000 propounds that delay is computed using the following equation shown below:

$$d = d1(PF) + d2 \qquad (2.4)$$

Where,

$$d1 = \frac{0.5C\ (1-\frac{g}{C})^2}{1-\left[\min(1,X)\frac{g}{C}\right]} \qquad (2.5)$$

$$d2 = 900T \left[(X-1) + \sqrt{(X-1)^2 + \frac{8kIX}{cT}} \right] \quad (2.6)$$

Where,

d = control delay, sec/veh

d1 = uniform delay, sec/veh

d2 = incremental delay, sec/veh

PF = delay adjustment factor for quality of progression

X = v/c ratio for each lane group

C = cycle length, sec

T = length of analysis period, hours

k = incremental delay factor, dependent on control settings

I = upstream filtering/metering adjustment factor

c = capacity of lane group, vph

g = effective green time for lane group, sec

2.5.3 Level of Service Analysis

As discussed above, delay is one of the important parameter to measure and define the level of service (LOS) for an at-grade urban signalized intersection, since delay not only indicates the amount of lost travel time and fuel consumption but it is also measures the frustration and discomfort of motorists. The factor on which delay depends is red time, which is further depending on the cycle length. Reasonable levels of service (LOS) can therefore be obtained for short cycle length, even the (v/c) ratio is as high as 0.9. The LOS criteria are given in term of the average stopped delay per vehicle during an analysis period of 15 min.

Level of service C described that level of operation at which delay per vehicle ranges from 20.1 to 35 sec. Many vehicles go through the intersection without stopping at level of service C, but a significant number of vehicles are stopped. In addition, not all vehicles at an approach clear the intersection during a few cycles (cycle failure). The higher delay may be due to the significant number of vehicle arriving during the red phases (poor progression) and or relatively long cycle lengths.

Level of operation at which delay per vehicle ranges from 35.1 to 55 sec is described by level of service D. Vehicles are stopped at the intersection as a result longer delay will occur at level of service D. The longer delay at this level of service is due to a combination of two or more several factor that includes high (v/c) ratios, unfavourable progression, and long cycle length.

Level of service E describes that level of operation at which the delay per vehicle ranges from 55.1 to 80 sec. Individual cycle's frequency fails at level of service E. This long delay, which is usually taken as the limit of accepted delay, generally indicates long cycle lengths, high (v/c) ratios, and poor progression. The number of individual cycles failing is now noticeable in level of service E.

The average control delay per vehicle is being estimated for each lane group and then aggregated for each approach and for the whole intersection. Level of service is directly related to the average control delay values. The above discussion to find the LOS is being shown below in tabular form:

Table 2.2 Level of Service from Control Delay (2000 HCM)

Level Of Service (LOS)	Control Delay / Vehicle (s/veh)
A	<10
B	20-30
C	20-35
D	35-55
E	55-80
F	>80

2.5.4 ICU Level of Service

The ICU Level of Service (LOS) gives us, how an urban signalized intersection is functioning and how much extra capacity is also available to handle traffic fluctuations and incidents. ICU is not only a value that can be easily measured with a stopwatch, but it does give us a good reading on the conditions that can be expected at the signalized intersection.

Letters from A to H shown in the table below describe the ICU level of service.

Table 2.3 Level of service criteria for ICU analysis

Intersection Capacity Utilization ICU	Level Of Service LOS
0-60%	A
>60%-70%	B
>70%-80%	C
>80%-90%	D
>90%-100%	E
>100%-110%	F
>110%-120%	H

2.6 What is Synchro/SimTraffic

The software Synchro can optimize phase orders, splits, offsets and cycle lengths. Synchro is user-friendly software. The major advantage of using Synchro is that an actuated and coordinated network can be simulate and optimize. Electronic file can easily import into the software so as to create the network of scale. Synchro has a data conversion feature among models including CORSIM that is very useful for the user. Another important feature is its map window that can display diagrams of traffic volumes and lane configuration and also draw links, nodes to define the networks. Editing is being allowed and volumes right on the map window and it is also convenient to input the timing data in timing window. Graphical representation is being viewed by using the splits and phasing diagram.

Synchro implements the Intersection Capacity Utilization (ICU) 2003 method for determining intersection capacity of signalized intersection. This method is a comparison of the intersections ultimate capacity to the current volume. Synchro also implements the methods of the 2000 Highway Capacity Manual (HCM) for signalized intersections. Synchro provides an easy solution for timing optimization and single intersection capacity analysis. In addition to calculating capacity, Synchro can also optimize splits and cycle lengths. Synchro optimizes the split, offsets, and cycle length. It is fully interactive, when we change input values, the results are updated automatically.

New outputs which are shown in the timing window also include the queuing penalty, queue length and stops, also the measures of effectiveness, the vehicle delay and LOS etc. Another feature Synchro is its project management tools that include tracking of multiple scenarios, dividing different projects into zones & split and combine files.

2.6.1 Functions of Synchro/Simtraffic

- Analyzes and optimizes a network of signalized intersections.
- It provides a detailed summary report on Capacity.
- Level of service, Volumes, No of Lanes.
- Signal timing.
- Queue lengths.
- Blocking problems.
- Delay/ stop and fuel consumption.

Chapter 3

RESEARCH METHODOLOGY

3.1 Introduction

The purpose of this chapter is to discuss the methodology used for this research so that to achieve research objectives those were discussed in Chapter 1. The chapter contains a methodology for analysing the capacity, delays and level of service (LOS) of at-grade urban signalized intersections. The analysis contains the existing traffic data on an I-8 signalized intersection, including the amount and distribution of traffic movements, traffic composition, geometric characteristics, and details of intersection signalization. The methodology focuses on the determination of LOS for existing and projected conditions.

The methodology addresses the capacity, LOS, and other performance measures for lane groups and intersection approaches and the LOS for the intersection as a whole. Capacity is evaluated in terms of the ratio of demand flow rate to capacity (v/c ratio), whereas LOS is evaluated on the basis of control delay per vehicle (in seconds per vehicle). Control delay is the portion of the total delay attributed to traffic signal operation for signalized intersections. Control delay includes, queue move-up time, stopped delay, initial deceleration delay, and final acceleration delay.

The methodology for capacity analysis for urban signalized intersections is based on known or projected signalization plans. Here we have a known I-8 signalized intersection. The procedure used consists of the data collection that is turning movements counts on I-8 signalized intersection, so to get the peak hour volume counts which further give us the peak hour factor. This peak hour volume and peak hour factor is further being used along with the existing cycle length and existing green time to determine the existing overall delay, capacity of each movement and for whole signal along with LOS and ICU with the help of software Synchro/simTraffic. The software used also optimizes the existing signalized intersection. This will further help us to find the solutions for future.

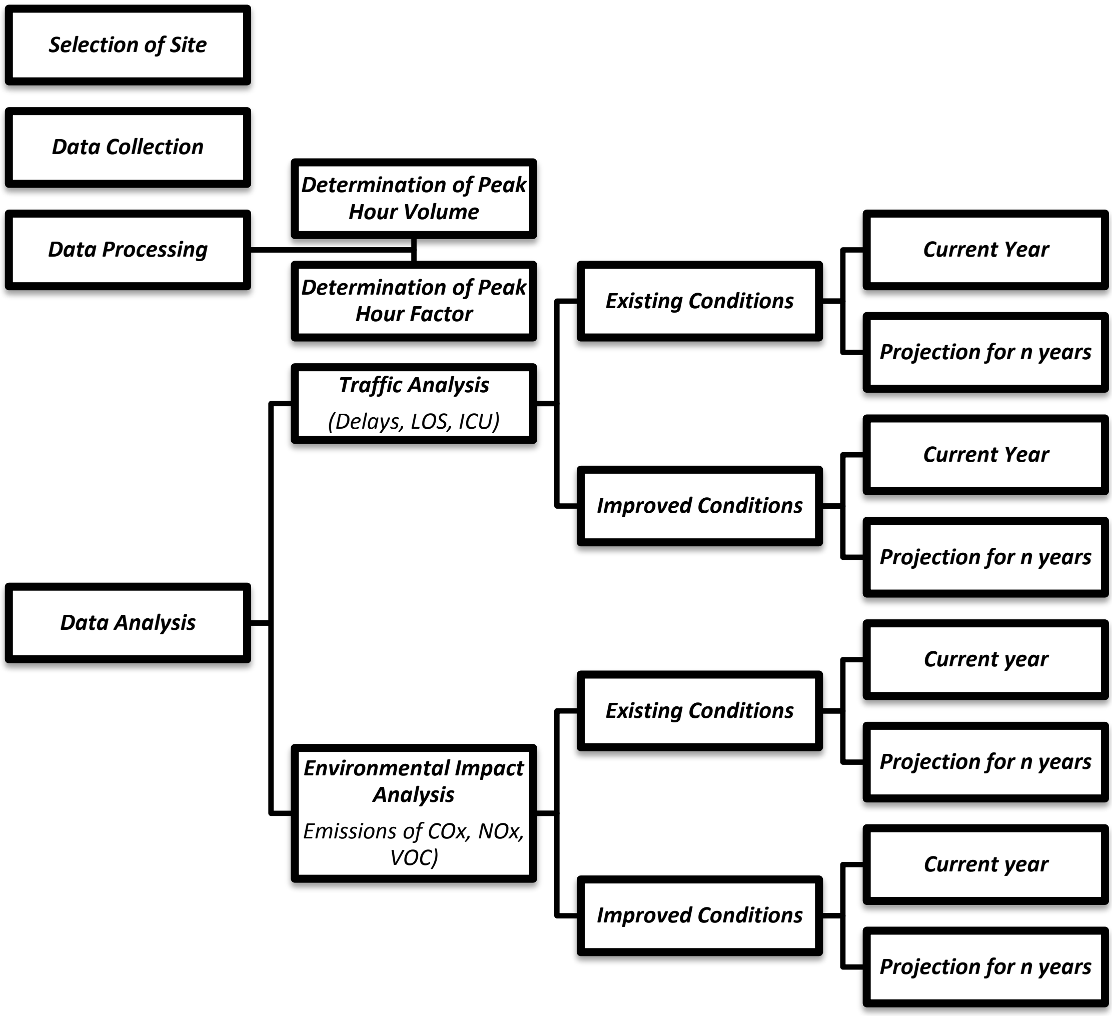

Figure 3.1 Flow Chart of Research Methodology

3.2 Method of Analysis of Signalized Intersections

Different methods are being used for the analysis of existing signalized intersection. The methods used are as follows:

- Quick Estimation Method
- Highway Capacity Manual (HCM)
- Arterial and Network Timing Models

- Microscopic Simulation Models

The method used here for the analysis of existing I-8 urban signalized intersection is HCM 2000.

3.3 Data Collection and Collation

The first step for the evaluation of signalized intersection is to collect the traffic data that is turning movement counts on the selected site. Our selected site is Koral Chowk signalized intersection on Islamabad highway. As our signal is pre-timed signal control, so, we have to collect the data for three days of week including weekday peak hours, weekend peak hours and holiday peak hours. So the days are Tuesday, Friday and Sunday. Here we collect the data of morning peak hour's starts from 8-11 am & evening peak hour's starts from 4-7 pm. Two options are available to collect the data signalized intersection. The options are:

- Manual Collection
- Jamar Traffic Data Collector

3.3.1 JAMAR Traffic Data Collector

Jamar data collectors are being used and known worldwide as the best. It is the most effective and efficient way of collecting traffic data manually. The JAMAR TDC Ultra is a single most effective and powerful hand-held tool for collection of traffic data now days. With the help of this one recorder, we can save countless hours by electronically collecting many types of traffic related data for easy download and also doing analysis with the powerful software known as PETRAPro.

The Jamar traffic data collector is an electronic hand-held device that enables us to measure the turning movement. An OFF/ON switch on top of the unit is being used to turn it on and off. A four line by 20-character display on the screen that helps us to select the proper entries. The bottom lines of the display explain the option that is highlighted.

Two buttons are used to move from one menu to another menu, and to select from the options as shown on the display screen. The TAB key is being used to cycle through the options and the DO key is used being to select an option.

Turning movement data is being easily collected from Jamar TDC as easy and accurate. The buttons are arranged as to simulate a standard signalized intersection. There are 16 buttons, in which 12 are used as for the left, through, and right movements from all the four approach directions. The additional four buttons are being defined by user; they can be used for pedestrians, bicycles, or whatever we want.

Figure 3.2 JAMAR TDC

The Jamar TDC Ultra looks like a 4-leg intersection, while doing a count is very intuitive. The Jamar TDC keeps track of everything else for us. At the end of every interval, the data is being automatically stored.

3.3.2 On Field Data Collection

As per selected site of Koral Chowk signalized intersection, we have to collect the turning movement counts on morning peak hours from 8 to 11 am and evening peak hours from 4 to 7 pm of Tuesday, Friday and Sunday. Fig 3.3 and Fig 3.4 shows below the pictorial view of existing at-grade urban signalized intersection at Koral Chowk Islamabad. Appendix-A shows the morning and evening peak hours turning movement counts, peak hour volume counts along with the peak hour factor (PHF).

Figure 3.3 Aerial View of Koral Chowk

Figure 3.4 An image of Koral Chowk

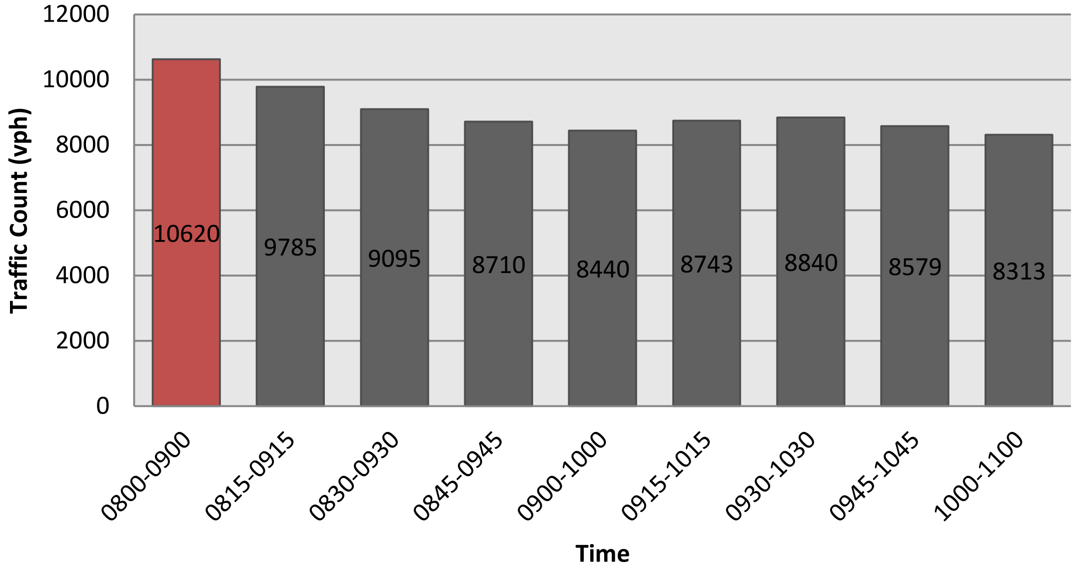

Figure 3.5 Graphical Representation of Peak Hour Volume on Friday Morning

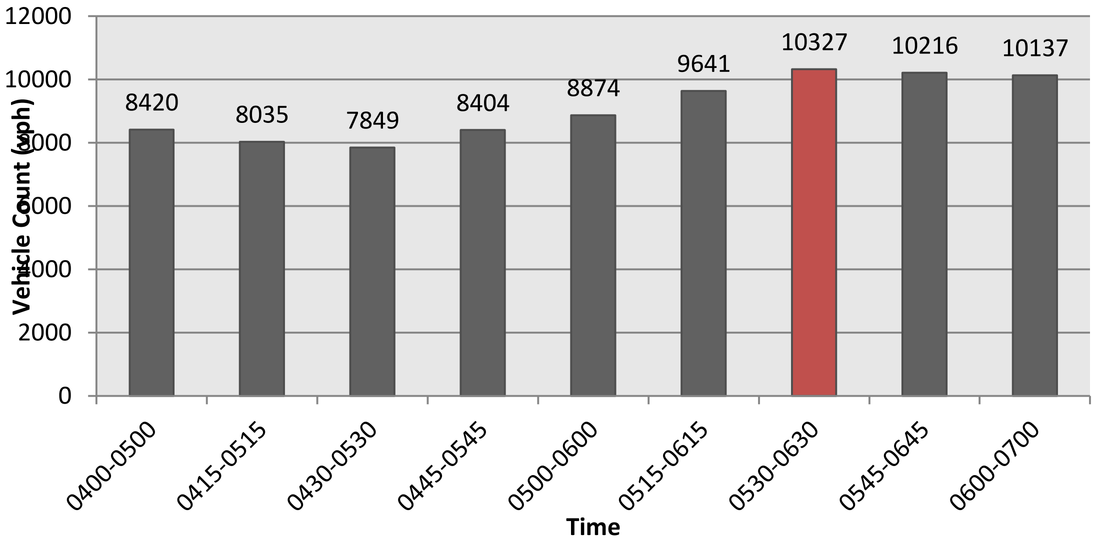

Figure 3.6 Graphical Representation of Peak Hour Volume on Friday Evening

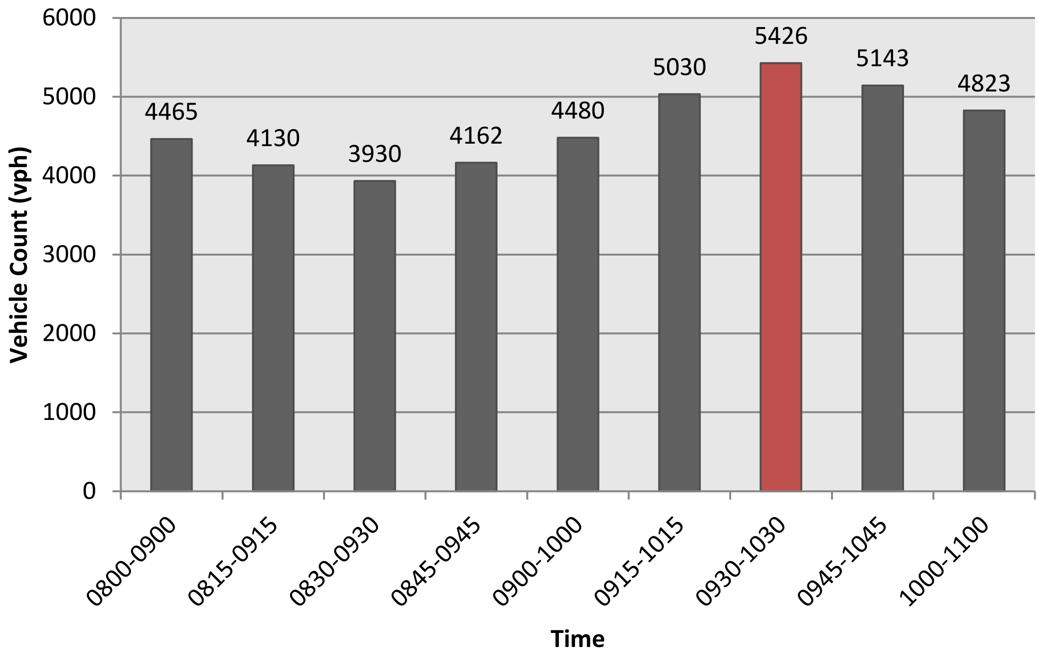

Figure 3.7 Graphical Representation of Peak Hour Volume on Sunday Morning

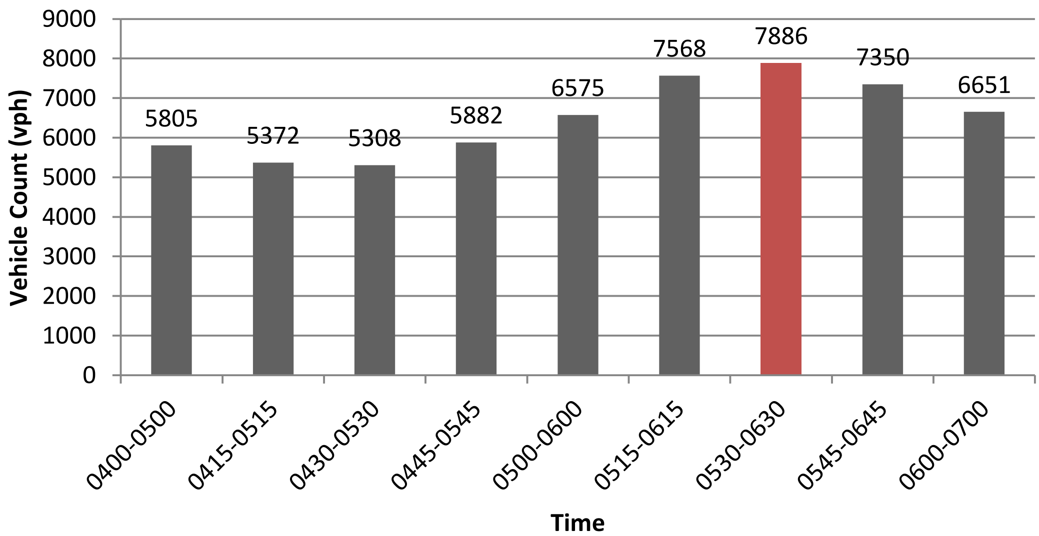

Figure 3.8 Graphical Representation of Peak Hour Volume on Sunday Evening

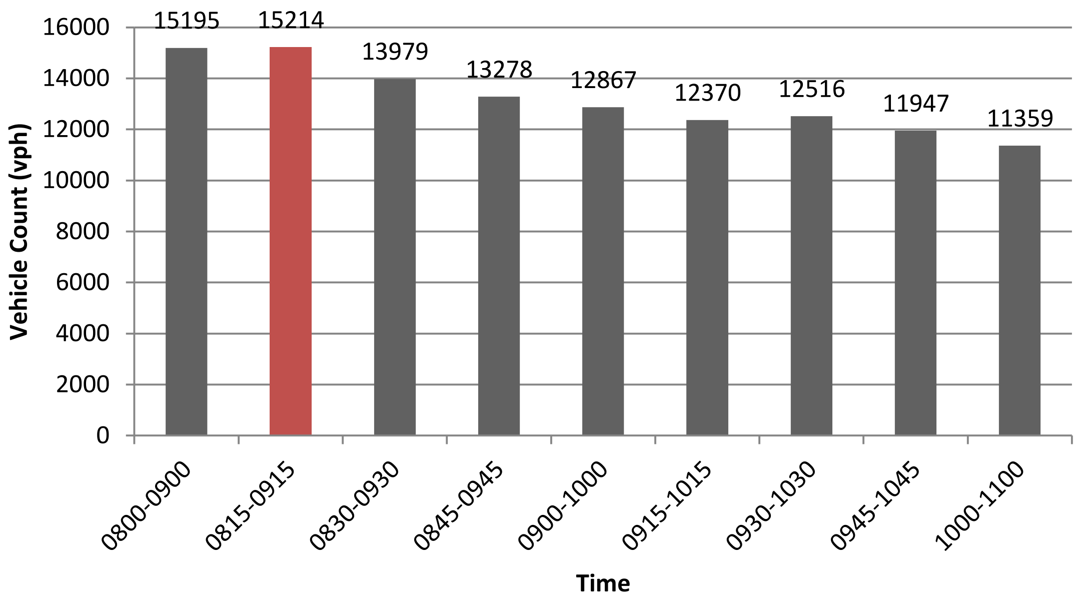

Figure 3.9 Graphical Representation of Peak Hour Volume on Tuesday Morning

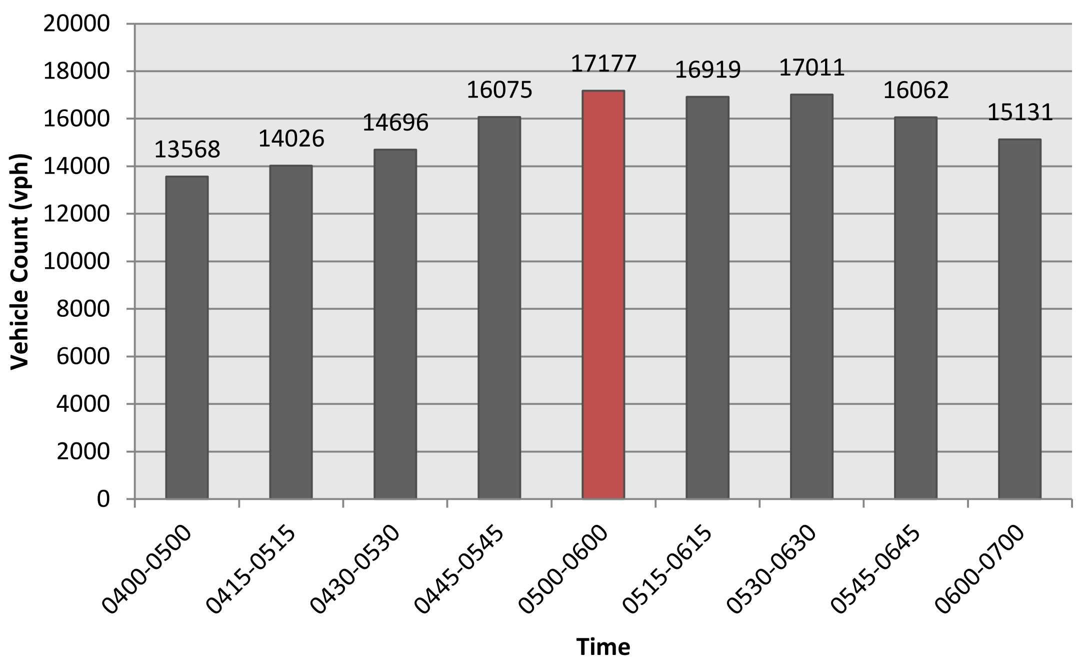

Figure 3.10 Graphical Representation of Peak Hour Volume on Tuesday Evening

Table 3.1 Summary Sheet of Morning and Evening Traffic Counts for Weekend, Holiday and Weekday

LOCATION: KORAL CHOWK, ISLAMABAD

Date 06/03/2015 **FRIDAY**

Time	From North			From South			From West			From East		
	Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
Morning	91	615	643	4939	1010	1245	206	3132	4157	1575	8820	940
Evening	90	463	480	4710	651	1608	517	9132	4837	878	3764	301

Date 08/03/2015 **SUNDAY**

Time	From North			From South			From West			From East		
	Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
Morning	125	670	493	1977	643	578	192	1465	1859	651	4369	716
Evening	179	935	685	2678	889	298	264	2016	2549	1047	6022	972

Date 10/03/2015 **TUESDAY**

Time	From North			From South			From West			From East		
	Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
Morning	192	1209	920	7071	1418	1763	296	4390	5975	2282	12501	1404
Evening	158	789	808	7893	1140	2800	875	14978	8133	1517	6307	514

3.4 Input Parameters

The input information that is being required for conducting an operational analysis for urban signalized intersections, a summary of it is given below. The data needed by us are detailed, varied and fall into three main categories. These categories are geometric, traffic, and signalization.

3.4.1 Geometric Condition

Urban signalized intersection geometry is presented in diagrammatic form and it also includes all of the relevant information, including the number and width of lanes, approach grades, and parking conditions. The existence of exclusive right-turn or left turn lanes must be noted, along with storage lengths of such lanes.

The onsite existing geometric parameters that should be important for the analysis of Koral Chowk signalized intersection are as follows:

- Area type
- Number of lanes, N
- Average lane width, W (ft)
- Grade, G (%)
- Existence of exclusive LT or RT lanes
- Length of storage bay, LT or RT lane, Ls (ft)
- Parking

3.4.2 Traffic Conditions

Traffic volumes (for oversaturated conditions must be used) for the signalized intersection. In our case the signalized intersection is oversaturated and we have to take the turning movements counts of each specified approach. The existing volume that is being collected is the flow rates in vehicles per hour (v/h) for the 15-mins analysis period. From the 15-mins analysis period the peak hour volume and peak hour factor of signalized intersection is being obtained as in our case we have already obtained the peak hour volume counts and peak hour factor.

Vehicle type distribution is another factor that should be kept in mind while doing analysis in our case it is quantified as the percent of heavy vehicles (% HV) in each and every movement, where the heavy vehicles are defined as those vehicles with more than four tires touching the road. The number of local buses on all approaches should be identified, including only those buses having a stop to pick up and discharge passengers at the signalized intersection (on either the departure or approach side). Buses not making such stops are considered to be heavy vehicles.

The onsite existing traffic conditions parameters that should be important for the analysis of I-8 urban signalized intersection are as follows:

- Demand volume by movement, V (veh/h)
- Base saturation flow rate, so (pc/h/ln)
- Peak-hour factor, PHF

- Percent heavy vehicles, HV (%)
- Approach pedestrian flow rate, vped (p/h)
- Local buses stopping at intersection, (buses/h)
- Parking activity, Nm (maneuvers/h)
- Approach speed, SA (mi/h)

Here in our case no extra lane is given for Pedestrian and bicycle so there factor are not to be consider. Same as for local bus stop as no local buses are on the route so there factor is not to be consider. Similarly for parking as no parking is there on our selected signalized intersection site so the factor for parking activity is not to be considered.

3.4.3 Signalization Conditions

Complete information regarding signalization is needed to perform an analysis. This information includes a phase diagram illustrating the phase plan, cycle length, green times, and change-and-clearance intervals.

The onsite existing signalization conditions parameters that should be important for the analysis of selected urban signalized intersection are as follows:

- Cycle length, C (s)
- Green time, G (s)
- Yellow-plus-all-red change-and-clearance interval
- (intergreen), Yellow (s)
- Actuated or pretimed operation

3.5 Analysis According to HCM 2000

Once we get all the existing traffic count data and traffic related data that is required for the analysis of at-grade urban signalized intersection, we have to perform the analysis according to HCM 2000 rules. According to HCM 2000 analysis is being performed manually or by using those software's doing analysis according to HCM 2000 rules. Here we used Synchro/simTraffic version 8.0 to perform the analysis of selected at-grade urban signalized intersection. As mentioned in chapter 2, following operations are required to do the performance evaluation of at-grade signalized intersection, these are:

- Capacity Analysis
- Delay Analysis
- Level of Service (LOS)
- ICU Level of Service

3.6 Summary

This chapter involves the methodology that has been followed to carry out this project in order to find out the results for existing conditions as well as for improved conditions. It involves the data collection whose summary has been given for weekdays, weekends and holidays in which we can find out that the peak hour volume is of Tuesday Evening and this volume will be used for further analysis.

Chapter 4

DATA ANALYSIS AND RESULTS

4.1 Introduction

In this research, Synchro/simTraffic version 8.0 was used for the evaluation of existing at-grade signalized intersection. The analysis includes the determination of capacity analysis, delays analysis, level of service and ICU level of service on existing conditions. Then optimization is being done so as to evaluate how the existing signalized intersection make more efficient and how the existing delays, capacity, level of service and ICU level of service make better, so as to reduce the number of delays, increase the capacity, make the level of service and ICU level of service better. Section 4.2 is an introduction about how the available data is being used to do the analysis using Synchro/simTraffic.. Section 4.3 show the existing delays, capacity, level of service and ICU level of service along with saturation flow rate, v/c ratio of all approaches and for the entire intersection. Section 4.4 shows all the above mentioned factors as discussed in section 4.3 after optimization with Synchro/simTraffic. Section 4.5 shows the comparison of results before and after optimization with Synchro/simTraffic.

4.2 Data Entry

This section describes the step by step procedure for the analysis and then optimization of signalized intersection using the software Synchro/simTraffic.

4.2.1 Layout Map of Koral Chowk

Koral Chowk urban signalized intersection is a 4-leg signalized intersection. It consists of Main Street (EB towards Rawalpindi and WB towards Islamabad) and Minor Streets (SB towards Benazir Airport and NB towards Koral Community). EB and WB consist of five through lanes. NB consist of one through right turn lane, one left turn lane and one right turn lane. SB consists of one right turn through lane, one left turn lane and one right turn lane. Each lane is 12 feet wide. Left turn lane is separated by an island at WB and NB. The existing cycle length is 290 seconds. Existing green time for WB is 100 seconds for through movements (including right turn movements). Existing green time for EB is 100 seconds for through movements (including right and left turn movements). Existing green time for NB is 60 seconds for through movements (including right turn movements). Existing green time for SB is 30 seconds for through movements (including right and left turn movements). Yellow times for all approaches are 3.5 seconds and all red time for all approaches are 0.5 seconds.

4.2.2 Lane Window of Synchro

- Ideal Saturation Flow is taken to be as 1900 veh/hr/lane.
- Lane Width is taken to be as 12 ft.
- As it is an at-grade signalized intersection so 0% grade is to be taken.
- Area type can be Central Business District or Other and there is an area type adjustment factor that is (0.9 for CBD and 1 for other areas) here we taken 1.
- Storage length is the number of lanes in the left or right storage bay. We take 400 ft for right storage lane.
- Total Lost Times take to be as 4 seconds for ideal situations.
- Storage Lane is one for right turn movement for EB movements.
- Leading Detector and Trailing Detector are only applicable for actuated signal analysis. As our case is pre-timed so they are not applicable in our case.
- Turning Speed is taken to be as 25 kph for left turn movement for WB and NB movements because of the provision of island and 15 kph for all other approaches.
- Lane Utilization Factor, FLU if there is more than one lane in a lane group and the lanes are not used equally, then we have to adjust the saturation flow in each of lane accordingly according to HCM 2000 and Synchro/simTraffic, so if number of lane is one then the lane utilization factor for left/right and thru lane is 1.But if number of lane is 2 or more as in our case then for thru or shared lane we take FLU=0.95 as in case of SB through movements. FLU=0.86 for four or more through or shared lanes. This value is used for EB and WB through movements.

- Right Turn Factor, FRT is taken to be as 0.85 according to HCM 2000 for exclusive lane (permitted case) and Left Turn Factor, FLT is taken to be as 0.95 according to HCM 2000 for exclusive lane(separated by island).
- Right Pedestrian Bike Factor, FRPB and Left Pedestrian Factor, FLPB are not applicable in our case as no separate pedestrian signal is provided and no separate lane for bike is provided.
- Saturation flow rate is being calculated by Synchro/simTraffic by using the formula as discussed in chapter 2 of section 2.5.1.
- Saturated Flow Rate (RTOR) is automatically calculated by Synchro/simTraffic based on the signal timing.
- Curb radius is taken to be 100ft for free lanes separated by island.
- Left turn factor (prot) is being calculated by Synchro/simTraffic.
- Right/left turn on red is not allowed.

4.2.3 Volume Window of Synchro

- Peak hour traffic volume for each movement is being given to Synchro/simTraffic with directions as thru, right and left turn to all four approaches.
- As there is no Conflicting ped/hr and Conflicting bikes/hr because no separate lane or lanes are being provided for both, so they are considered.
- Peak Hour factor or factors that are being calculated for all lanes are to be given to Synchro/simTraffic.
- Growth Factor is calculated as $GF= (1+r)^Y$, here r= growth rate and Y= number of years. As analysis is being done on current year so it is taken to 1.
- Heavy Vehicle (%) as it is an urban signalized intersection there is not much of heavy traffic so we take default value of heavy vehicle percentage that is 2.
- As no adjacent parking lane is available, so it is not considered.
- Bus Blockages (#/hr), Presence of Parking Lane & Parking Maneuver (veh/hr) these factors are not consider as discussed in chapter 3 of section 3.4.2.

- Adjusted Flow and Lane Group Flow is being calculated by Synchro/simTraffic using the formula shown below:

  Volume*PHF*GF (4.1)

4.2.4 Timing Window of Synchro

- Controller type, we must specify the controller type as pre-timed, actuated coordinated, actuated uncoordinated, semi actuated uncoordinated, unsignalized and roundabout. As in our case it is a pre-timed signalized intersection.
- Cycle length is taken to be as 290 seconds on existing conditions.
- Turn type is being selected as protected for all right turn movement and left turn movements except for left turn movement on WB and NB movements because left turn movement is separated by island.
- A typical value of minimum initial of 4 secs is to be taken.
- A typical value of minimum split of 8 secs is to be taken.
- Yellow time is taken to be as 3.5 sec and all red time is taken to be as 0.5 secs as discussed in section 4.2.1.
- Actuated effective green and actuated g/c ratio is not to be considering as we are doing analysis on pre-timed signalized intersection.
- Capacity analysis is being done by Synchro/simTraffic automatically using the formula as discussed in chapter 2 of section 2.5.1.
- Once the capacity of all approaches and for whole intersection is being obtained then v/c ratio is being calculated.
- Control delays of all approaches and for whole intersection is being calculated by Synchro/simTraffic as discussed in chapter 2 section 2.5.2.
- Level of service for all approaches and for whole intersection is being calculated according to the delay criteria as discussed in chapter 2 of section 2.5.3.
- ICU level of service for whole intersection is being calculated according to the criteria discussed in chapter 2 of section 2.5.4.

4.3 Existing Results before Optimization

As the analysis is being done on Synchro/simTraffic version 8.0 so we should know the existing condition of I-8 signalized intersection. Synchro/simTraffic has the quality not only to optimize the signalized intersection but also show us the existing traffic condition. Here we discuss the existing traffic condition and their results before optimization.

Fig 4.1 shows us the Synchro/simTraffic result showing the turning movement volume counts of all approaches and also show the directions. Fig 4.2 shows the v/c ratio of all approaches. Here those approaches where the v/c ratio is greater than 1 are critical and these approaches are to be optimized which in our case can be seen that each and every approach needs optimization. Fig 4.3 shows us the intersection control delay of all approaches and also the overall intersection control delay. As we know where the control delay is greater than 80 or more then level of service for that approach is F as discussed in chapter 2 of table 2.2. The approaches where the control delay is greater than 80 or more are to be optimized by Synchro/simTraffic so as to make them less than 80 which also reduces the level of service for that approach from F to E or D so on. Fig 4.4 shows us the intersection level of service that is F and turning movement’s counts of all approaches as discussed before. As we discussed that where the control delay is 80 or more than the existing level of service is F. Here the control delay is 160.7 so the existing level of service is F. The existing level of services of all approaches is being shown in appendix-I. Fig 4.5 shows us the intersection capacity utilization (ICU) that is 195.5%. As we discussed in table 2.3 of section 2.5.4, if ICU is 120% or more then level of service is H.

Figure 4.1 Turning movement Volume Counts of all approaches

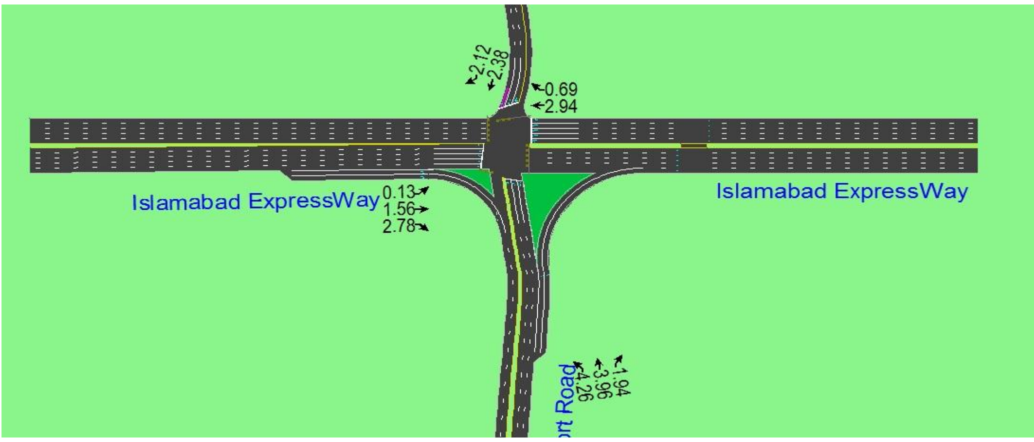

Figure 4.2 Volume to capacity ratio of all approaches before optimization

Figure 4.3 Intersection Delays and Movement Delays before optimization

Figure 4.4 Intersection Level of service and turning movements before optimization

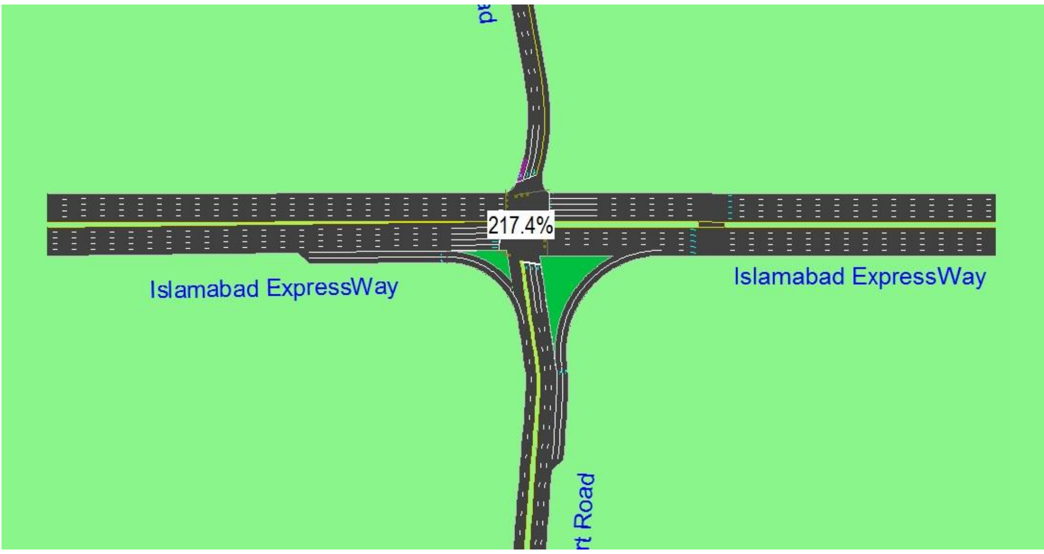

Figure 4.5 Intersection Capacity utilization (ICU) before optimization

4.4 Results after Optimization

After the optimization of Koral Chowk urban signalized intersection, the results are changed from existing condition. But still the intersection level of service remains the same that is F. The ICU is also remains the same as 217.4%. The changes occur in capacity, v/c ratio and the intersection control delays of all approaches and intersection overall delay.

Fig 4.6 shows the v/c ratio off all approaches after optimization in which 2.89 is the maximum v/c ratio. Still there are approaches where the v/c ratio is greater than 1, so these approaches still need solution so as to make their v/c ratio less than 1. Fig 4.7 shows us the intersection control delay of all approaches and also the overall intersection control delay. The result shows us that there is changes occur in control delays of all approaches and also the control delay of overall intersection. Here the overall intersection control delay is reduces from 844 to 719.3, but still there is no change occur in the level of service as it remains the F. It is because the control delays are still greater than 80 as discussed in chapter 2 of table 2.2. Fig 4.8 and fig 4.9 shows level of service and ICU along with the turning movement counts. Both level of service and ICU remain the same as before the optimization. The ICU level of service also remains the same as H, shown in appendix II.

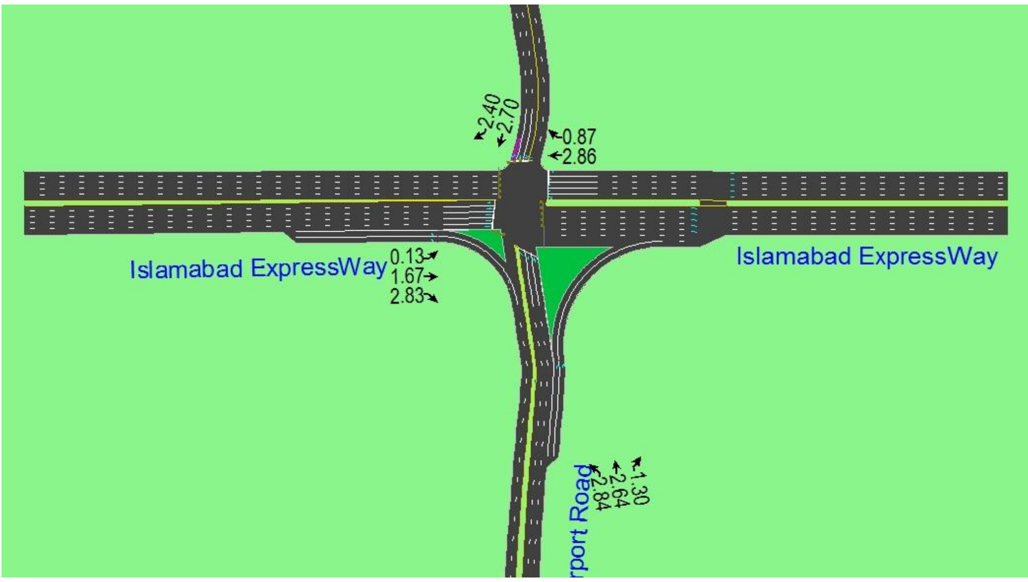

Figure 4.6 Volume to capacity ratio of all approaches after optimization

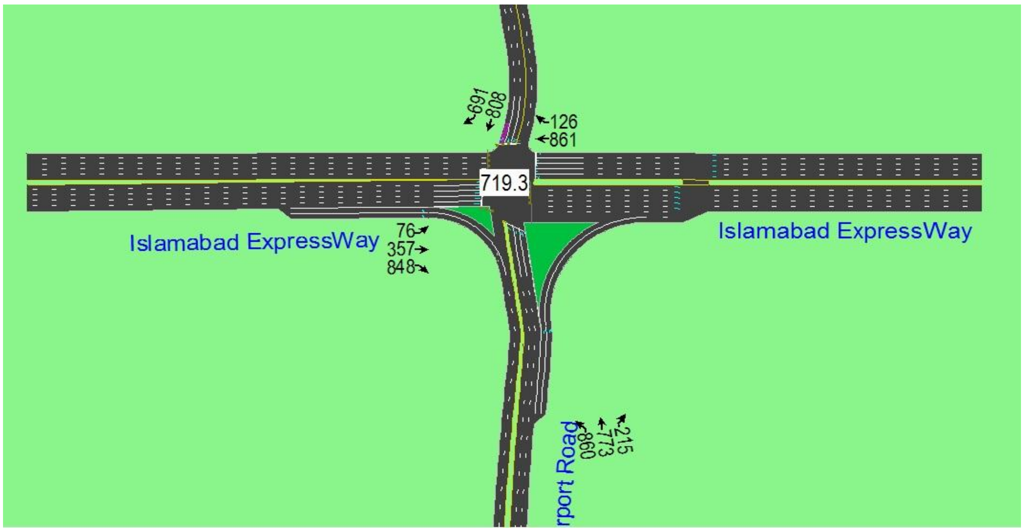

Figure 4.7 Intersection Delays and Movement Delays after optimization

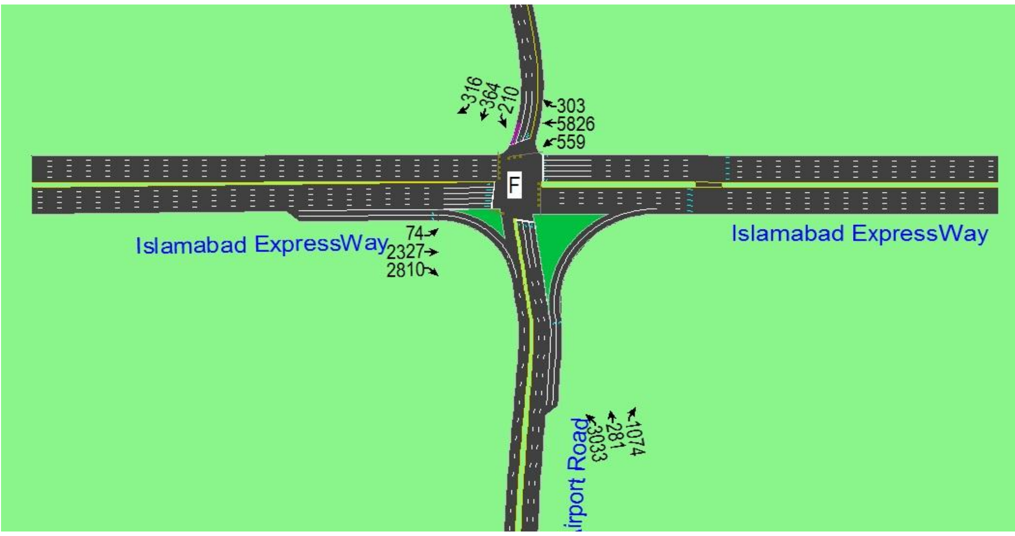

Figure 4.8 Intersection Level of service and turning movements after optimization

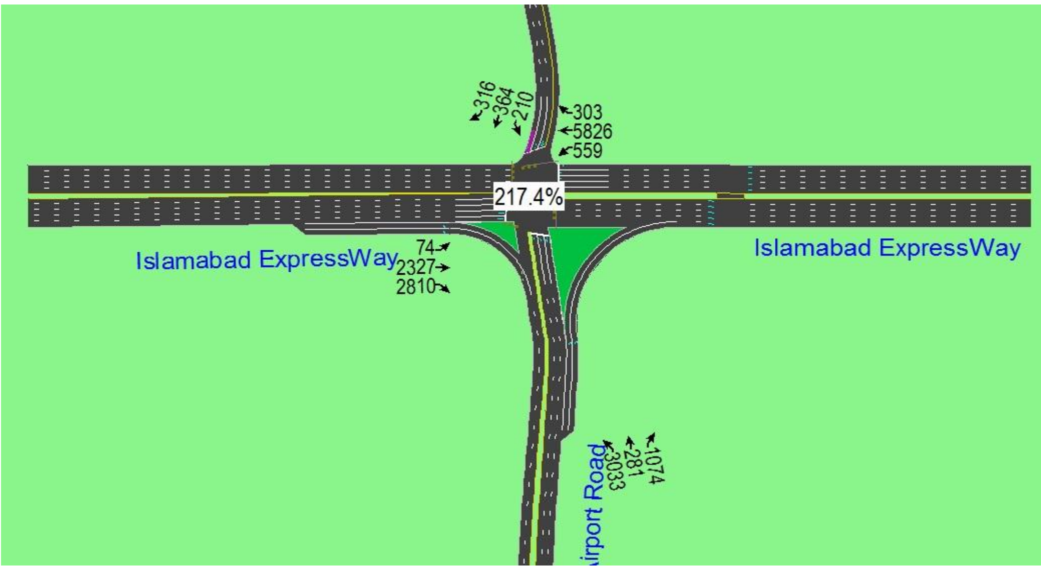

Figure 4.9 Intersection Capacity utilization (ICU) after optimization

4.5 Results Comparison

There are differences between the existing results and after optimization results of Koral Chowk urban signalized intersection. Here we present the differences between the existing conditions and after optimization conditions.

Table 4.1 Comparison of results before and after optimization

Parameter	Before Optimization	After Optimization
Cycle Length	306	300
Control Type	Pretimed	Pretimed
Max V/C Ratio	4.26	2.86
Intersection Signal Delay	844.0	719.4
Intersection Capacity Utilization (ICU)	217.4%	217.4%
Intersection LOS	F	F
ICU LOS	H	H

4.6 Comparison of Simulation Results Before and After Optimization

Table 4.2 tabulates the comparison of average results before and after optimization.

Table 4.2 Simulations results comparison before and after optimization

Run Number	Before Optimization	After Optimization
Start Time	6:57	6:57
End Time	7:10	7:10
Total Time (min)	13	13
Time Recorded (min)	10	10
# of Intervals	2	2
# of Recorded Intervals	1	1
Vehs Entered	1110	1065
Vehs Exited	1064	1000
Starting Vehs	384	436
Ending Vehs	430	500
Travel Distance (mi)	401	377
Travel Time (hr)	268.5	266.1
Total Delay (hr)	254.2	252.5
Total Stops	1100	1088
Fuel Used (gal)	72.5	71.3

4.7 Synchro Results after 5 years

Using the traffic growth rate of 15% and projecting the traffic to 2020, the results have been calculated using Synchro.

Fig 4.10 shows us the Synchro/simTraffic result showing the turning movement volume counts of all approaches and also show the directions. Fig 4.11 shows the v/c ratio of all approaches. Here those approaches where the v/c ratio is greater than 1 are critical and these approaches are to be optimized which in our case can be seen that each and every approach needs optimization. Fig 4.12 shows us the intersection control delay of all approaches and also the overall intersection control delays. Fig 4.13 shows us the intersection level of service that is F and turning movement's counts of all approaches as discussed before. Fig 4.14 shows us the intersection capacity utilization (ICU) that is 424.8%.

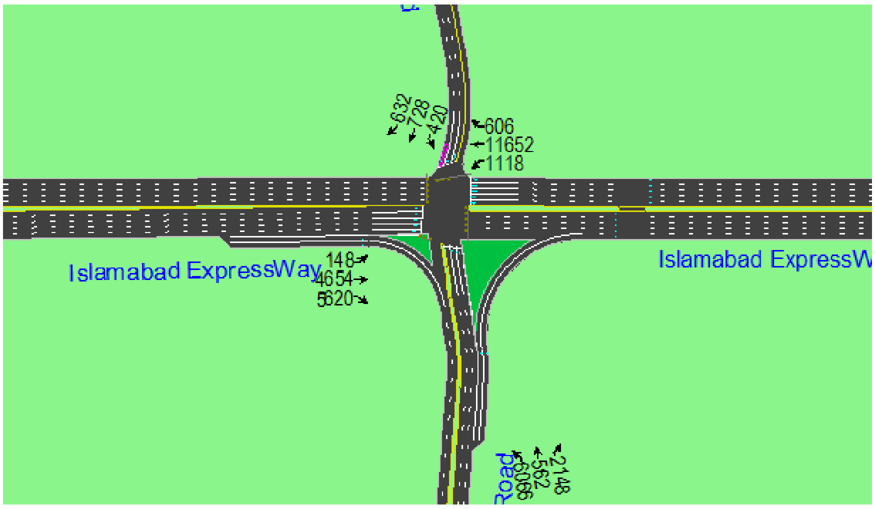

Figure 4.10 Turning movement Volume Counts of all approaches in 2020

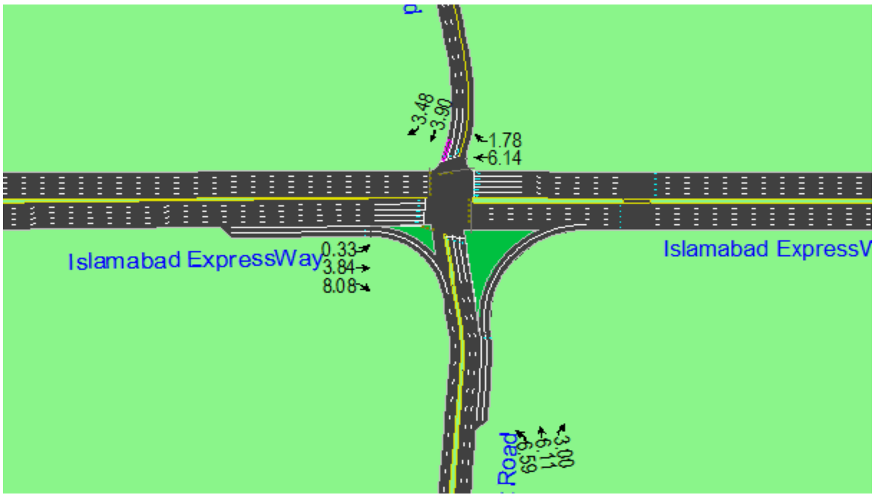

Figure 4.11 Volume to capacity ratio of all approaches in 2020

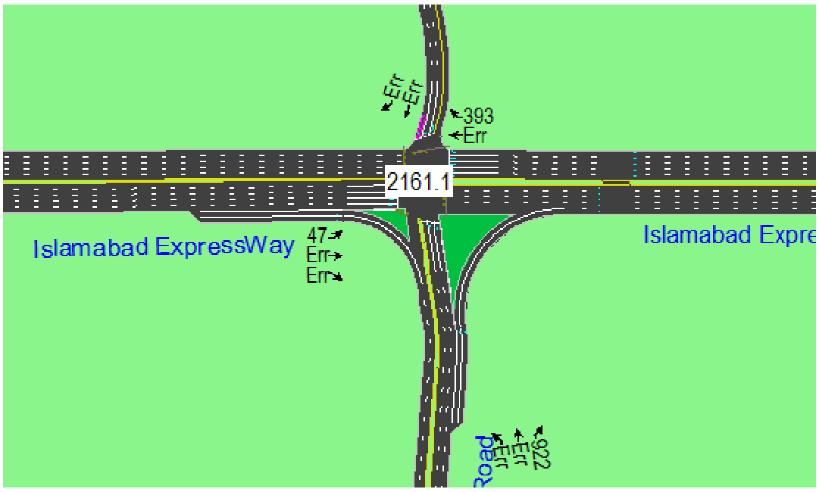

Figure 4.12 Intersection Delays and Movement Delays in 2020

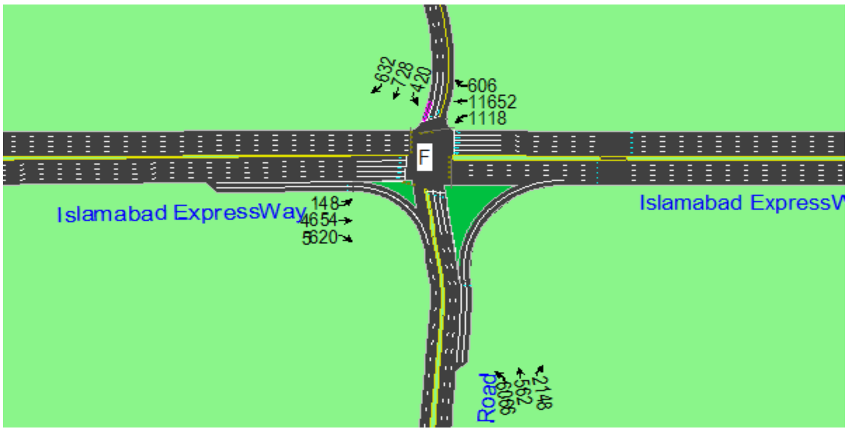

Figure 4.13 Intersection Level of service and turning movements in 2020

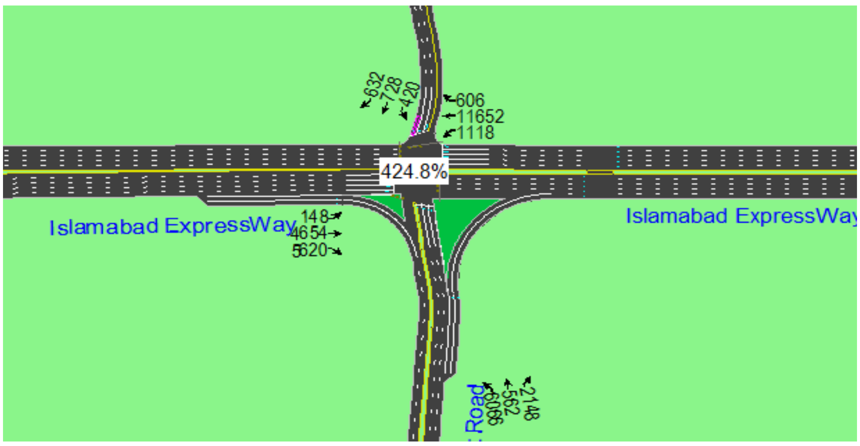

Figure 4.14 Intersection Capacity utilization (ICU) in 2020

4.8 Summary

This chapter includes the data entry into the software. It involves and explains all the parameters that are required by Synchro to carry out the analysis including lane information, layout map, volume data and timing details i.e. phasing. This chapter gives results of the existing conditions before optimization such as v/c ratio, delays, LOS and ICU as well as after optimization. A comparison has also been drawn to compare the results before and after optimization.

The existing conditions have also been projected for five years using a growth factor of 15% to see the results and conditions during 2020 and are compared with existing results.

Chapter 5

RECOMMENDED SOLUTIONS AND ENVIRONMENTAL IMPACT ASSESSMENT

5.1 General

The Research was primarily aimed at studying the performance evaluation of at-grade urban signalized intersection. After all the analysis, it is found that the LOS of the intersection even after optimization remains the same i.e. F. In such cases, we go for a grade separated facility such as flyover etc. to improve the performance of the facility. This chapter deals with the ways to improve the performance of facility and discusses its analysis.

5.2 Proposed Solution

As the LOS of the whole intersection after optimization remains the same i.e. F, therefore the only solution is grade separation.

A grade separated facility i.e. a flyover carrying the EBR traffic will improve the existing conditions. Add one lane to EBT and WBT direction so that total number of lanes in EBT and WBT becomes 6. Provide an exclusive lane in all directions each having a curb radius of 150m. Provide 2 storage bays each of length 400m in EBL, WBL, WBR, and NBR direction. Provide one storage bay of length 400m in EBR direction. The EBL and WBL storage bays will accommodate for traffic turning in the specified directions.

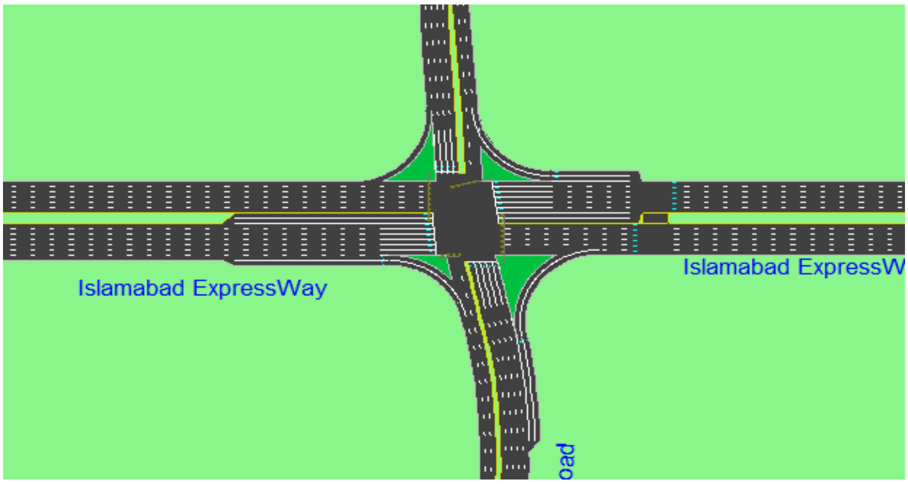

Figure 5.1 Proposed layout of Koral Chowk

Yellow time will be taken as 3.5 seconds. All red time is taken as 0.5 seconds. A total of 4 phases will be installed. The 1st phase will carry the EBL and WBL traffic having a total split of 32 seconds. The 2nd phase will carry the EBT and WBT traffic having a total split of 74 seconds. The 3rd phase will carry the NBT and NBL traffic having a total split of 60 seconds. And the 4th phase will carry the SBT and SBL having a total split of 34 seconds. The total cycle length in this way will be reduced from 306 seconds to 200 seconds. Figure 5.2 shows the v/c ratio of all approaches. Figure 5.3 shows the control delays of all approaches.

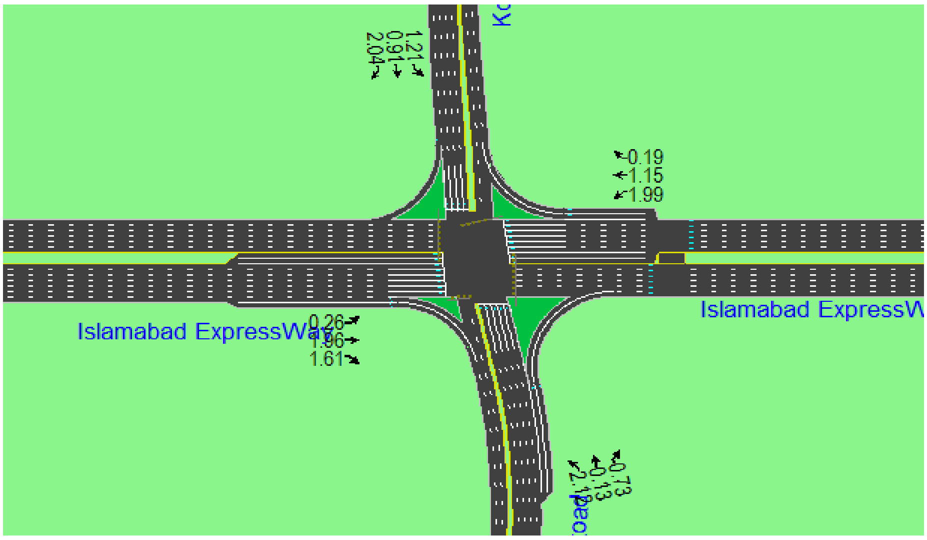

Figure 5.2 V/c ratio of Proposed layout of Koral Chowk

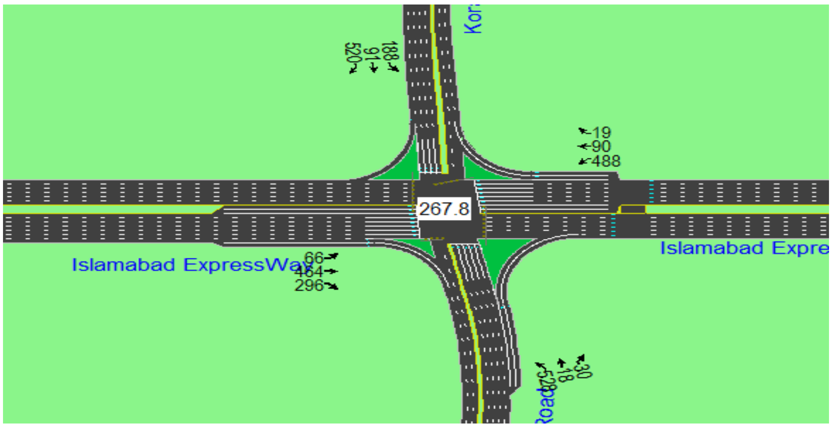

Figure 5.3 Control delays of Proposed layout of Koral Chowk

5.3 Projection till 2020

Using a growth factor of 15%, the existing data is projected till 2020 to observe the results after 5 years. The details are given below.

Figure 5.4 shows the v/c ratio of the proposed facility in 2020. Figure 5.5 shows the control delays of the proposed facility in 2020.

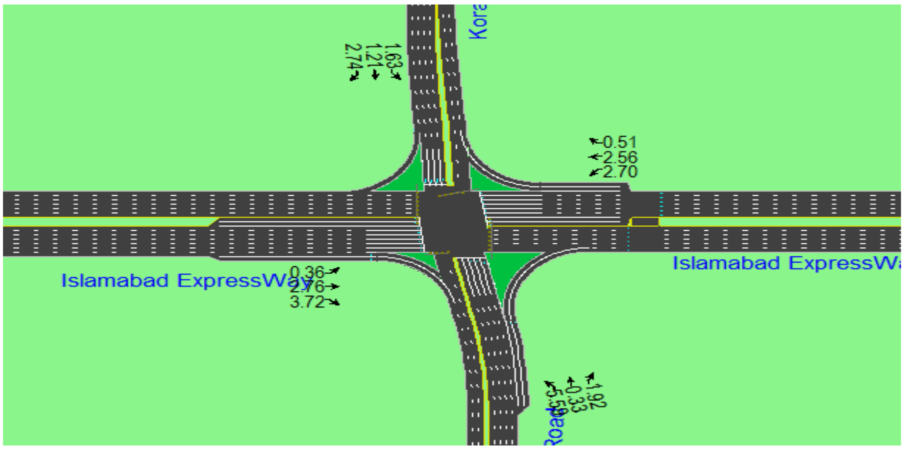

Figure 5.4 V/c ratio of proposed facility in 2020

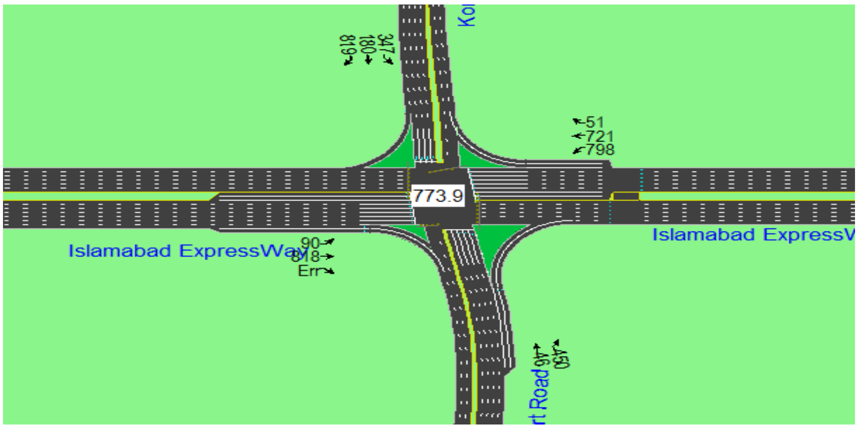

Figure 5.5 Control delays of all approaches of proposed facility in 2020

5.4 Comparison of results before and after improvement

Table 5.1 shows the comparison of results before and after improvement, both for 2015 and 2020.

Table 5.1 Comparison of results before and after improvement

Parameter	Existing 2015	Improved 2015	Existing 2020	Improved 2020
Cycle Length	306	150	150	220
Max v/c ratio	4.26	2.12	6.59	5.59
Control Delay	844	267.8	2161.1	1003.9
Intersection Capacity Utilization (ICU)	217.4%	172.4%	424.8%	334.8%
Intersection LOS	F	D	F	F

5.5 What is Environmental Impact Assessment?

Environmental impact assessment is a formal process whereby we predict the environmental consequences (positive or negative) of a plan, policy, program or project prior to the implementation decision; it suggests measures to adjust consequences and impacts to an acceptable level or else look for better technological solutions. Sometimes this assessment may lead to difficult economic decisions complemented with political and social concerns, environmental impact assessments protect the environment by providing a firm basis for efficient and sustainable development. The first EIA system was established on the 1st January 1970 by the US National Environmental Policy Act (NEPA). The implementation of this legislation was sought primarily as a response to political factors which included changing scale and nature of industrial development post World War II, increase in public distaste about environmental consequences of economic development and the failure of previously utilized methods to make such decisions including Cost Benefit Analysis.

The primary Objective of such an Assessment is to educate the decision makers about the possible consequences that their expected decisions face. The International Association for Impact Assessment (IAIA) defines an Environmental Impact assessment as “The process of identifying, predicting, evaluating and mitigating the biophysical, social, and other relevant effects of development proposals prior to major decisions being taken and commitments made”. EIA’s do not require close submission to existing norms and predetermined values for the environmental deterioration parameters. These numbers only serve as a reference for the decision maker to justify his/her decision in light of the various concerns and impacts.

5.6 Description of Existing Environment

The last decade has seen an unprecedented increase in vehicular emissions in the Koral Chowk Intersection, Islamabad interlinking the busiest of arterials amongst the city, resulting in severe traffic congestion and bottlenecks formations which is the root cause contributing towards excessive delays, unacceptable air and noise pollution, and related socio-economic problems for the daily highway users. The improvement of the overall traffic conditions along the Koral Chowk, Islamabad is the primary objective of this comprehensive traffic study being performed for this intersection. The study's main objectives are as follows:

- To provide for smooth, uninterrupted traffic movements along the Intersection
- To reduce delays and traffic congestion at the major junctions
- To reduce the travel times along the Intersection
- Reduce the noise and air pollution due to static vehicles at intersections
- To minimize the economic losses due to traffic congestion and delays along the Intersection

In short, the main study objectives of conducting this project are to improve the overall traffic flow efficiency along the intersection achieved through the coordination of signals and the subsequent implementation of traffic management plans at intersection, resulting in considerable decrease in traffic delays, lower fuel consumption which in turn leads to fewer environmental problems. Not only the environment will be better placed after the implementation of the proposed traffic plans, but also they will encourage the alleviation of socio-economic problems encountered by the road users who travel through Koral chowk.

5.7 Economic Impact Analysis

The government of Pakistan's 2011 Framework for Economic Growth (GoP 2011b) seeks to propel Pakistan towards a highly sustainable economic growth plant that will see it attain a growth rate of approximately 7 percent a year. The trade and transport reforms from the cardinal principles behind this framework as the government recognizes the true importance of an efficient carrier network of goods and passenger that will bolster the economy only higher. The transport sector constitutes 10 percent of Pakistan's gross domestic product (GDP), providing employment to approximately 6 percent of total work force. The sector forms key linkages to other sectors of the economy contributing towards the facilitation of the spatial transformations occurring in Pakistan. The patterns of transport and logistics experienced at this time have been effecting the country's GDP by a hefty chunk of 4-6%.

Hence it is imperative that transportations systems are designed to their optimum conditions as to reap the rewards of such a system by generating revenues for the country. It is evident that how big a contribution these transport entities provides in terms of income to the country as well for the people who form the chunk of the workforce. Federal and provincial governments meanwhile can also levy taxes that further increase the country's treasury.

The level of transportation facilities determines the energy consumptions (fuel consumption) by the vehicles with subsequent betterments in traffic stream characteristics and will consequently lead towards improvements in traffic operations which will lower the energy consumptions saving precious fossil fuels and adding to the economy as a whole. For sustainable transportation projects, the important goals are to reduce fuel consumption and resulting emissions caused by the burning fuels resulting in air pollution. A reduction in fuel consumption can be guaranteed by improving traffic flow conditions along the highways and urban arterials by utilizing the latest, state of the art technologies.

These technologies vary in form and function. First and foremost recent industrial developments have led to the manufacture of fuel efficient automobiles with much lesser emissions than their counterparts. This efficiency is brought about by using catalytic converters which convert the harmful gases into harmless greenhouse gases. These, however are not ideal in the numbers they have been emitted over recent past hence better engine technologies are envisaged to reduce such emissions. Traffic safety can be provided by better use of traffic control devices and integrated traffic management systems as well as the intelligent transport systems branch. Increase in traffic volumes can be alleviated by using GPS and GIS application in sync with live traffic forecasting models.

The most basic of these measures is to reduce the fuel consumption by minimizing the static time spent by automobiles at busy intersections. Signal coordination methods, traffic management plans ensure that these delays are reduced to an extent that they considerably contribute towards lowering of the emission amounts. This aspect of the transport model can be corroborated by studying past intersection analysis studies which show a direct correlation between emissions and increased delays. This matter of fact makes the present day engineer more aware of this surroundings and aiming to provide better transport models that can prove to be sustainable in addition to providing the traditional road user benefits of convenience, safety and comfort.

It can be stated with increased amounts of certainty that under the prevalent conditions, converting a signalized intersection into an interchange will result in uninterrupted traffic flow preventing the driver from unnecessary deceleration/acceleration while approaching the intersection at a constant speed without the urge to apply hard braking near stop lines of the intersection resulting in fuel efficiency. In today's world everything is interlinked to virtually every other thing making the roads connecting these items of necessity and luxury seen as an economist's worst nightmare. The potential impacts studied include direct, indirect and cumulative impacts of the project. Cumulative impacts are the incremental impacts that the project's direct or indirect effects have on a resource in the context of the multitude of other past, present and future effects on that resource from unrelated activities. This usually translates to commodities which are being transported through these transportation systems. Below are some of the comparison performed which explain the cost comparison between built scenario costs (improved traffic intersection) and no built scenario (if prevailing conditions remain in the future as well) costs. The charts clearly demonstrate the traffic corridor with suggested improvements (traffic management, signal coordination etc.) will yield economic benefits of lowering the fuel consumption which in turn lowers costs. The first table depicts the annual costs associated with the prevalent delays present in the traffic corridor and a scenario where these have been reduced.

For the purpose of this study the output of Synchro "fuel usage (gallons) was utilized. This fuel usage was multiplied by a conversion factor to obtain fuel usage in litres as this is the unit prevalent in Pakistan for measuring fuel rounded off to the nearest litre with the prevailing fuel prices. In this case as of May 25 2015, the rate set by OGRA was found to be RS. 74.29 per litre, this number was multiplied by the fuel consumed in litres at every intersection to obtain the total costs for fuel consumption per peak hour of the vehicles passing through the respective intersections.

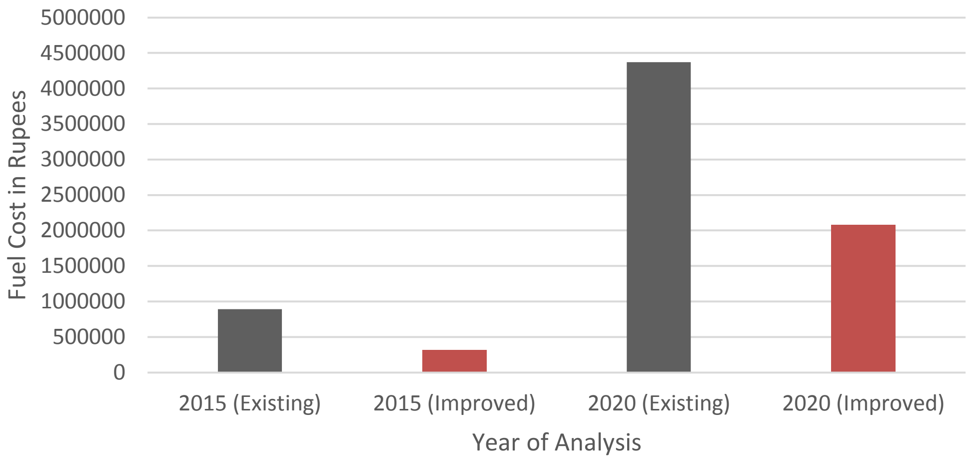

Figure 5.6 Fuel Costs for Existing and Improved Scenerios

5.8 Social Impact Analysis

The social impacts of transport facilities are unique in terms of how they affect the users as compared to other forms of impacts such as economic, environmental and convenience. Social environment differs from place to place and this impact depends upon the level of anticipation, social change interpretation and affected population resilient index. In recent years, more concentration is given to the effect of transportation on the society while regard for road users is kept to a bare minimum. The social aspects of transportation system can be better quantified by keeping in mind the following two notions:

- These effects could be substantial
- They affect the quality of life of the people

For the analysis, it is important to apply the best possible method because social and economic effects of transportation system are generally complex because of the following four reasons:

- There must be a balance between the benefits provided to the users of the facility and community residents
- Major and minor effects of the system on the communities are also considered in the analysis

- There are population groups in the communities, the might be affected in different ways in terms of mixes of effects
- The preference and acceptability of something vary from person to person. Something that is acceptable to someone might not be acceptable to others.

The changes in transportation system are substantially influenced by changes in transportation costs. These costs include the travel time, safety and operating cost of the vehicle. Hence an important doctrine to keep note of is the inability by the transport planning authorities to cater for everyone's needs. There has to be a balance stricken and priority matrices devised in ordered to best meet the demands of the population at large with fewer exceptions.

5.9 Environmental Impacts

A major issue discussed on global forums has been the increasing contribution of the transport sector towards greenhouse gas emissions emanating from the never ceasing fossil fuels culminating in consequential global warming and climatic change. Although there have been a number of technological advancements over the past few years which has resulted in improved vehicle and engine design and maintenance technologies, zeroing in at minimizing fuel usage, increasing speed , engine performance and the enhancement of its life. Such advances have also pushed for more developments in transport sector with newer methods being utilized for road construction and design, planning urban settlements, laying a great deal of emphasis on cleaner burning fuels. The planning, optimization of resources, and application of scientific methods has resulted in addressing the problems which are relatively new in their origin.

Air pollution poses a great risk to the road users as well as the populace that make up the habitat surrounding these busy road networks. Transportation contributes towards ambient air pollution, a major health risk and prevalent in our country according to a World Bank report. The main sources of these pollutants include static as well as mobile sources. The transportation sector's share in the ambient air pollution caused in urban areas is considerable. According to a similar World Bank report there have been 22600 deaths reported per year, directly or indirectly attributed to ambient air pollution. A 2011 report puts the number of pollution related deaths to 10,000 in the province of Sindh alone.

Quantifying the parameters associated with the enumeration of the effects that transportation entities pose on the environment is such a tricky task. However, software such as SYNCHRO lets us simulate traffic flow conditions according to volume of parameters which can help us distinguish the effects that automobiles have on subsequent charts will show the differing amounts of these pollutants expected at various intersections along the study area.

5.9.1 CO Emissions

CO or Carbon Monoxide emissions are a common occurrence in the exhaust fumes of the vehicles. High level of CO are extremely dangerous and can lead to death in extreme scenarios, for example turning on the ignition of a vehicle inside a closed garage. A number of diseases are caused by this pollutant and it is imperative to keep the daily intake of CO to minimum as it affects the efficiency of the Red Blood Cells of the human body to carry out its function of delivering oxygen to every component of the body. The following comparisons show emissions for current (2015) and 5-year projection (2020).

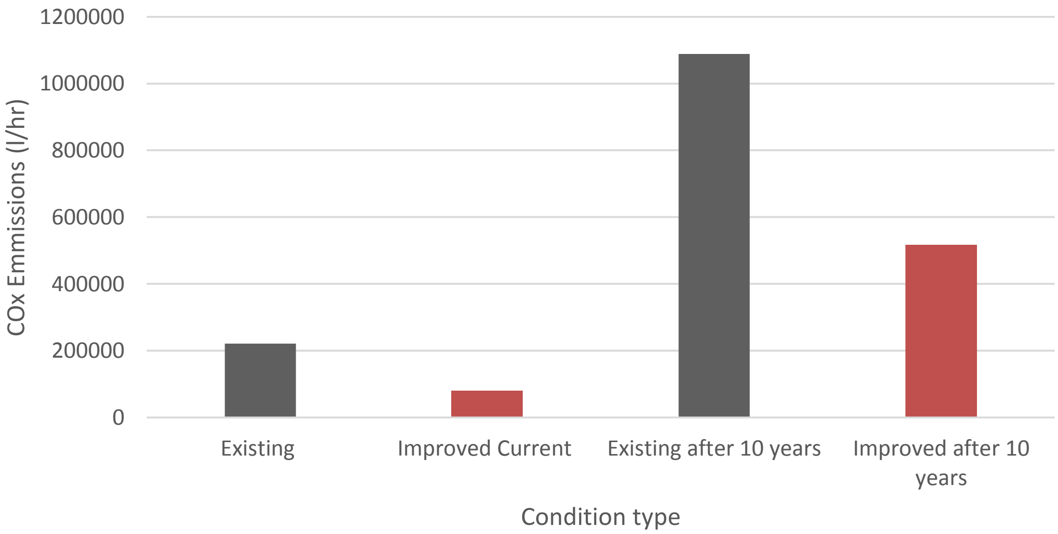

Figure 5.7 CO Emissions For Existing and Improved Conditions

5.9.2 Oxides of Nitrogen

Oxides of Nitrogen (NO_x) consists of Nitric Oxide (NO), Nitrogen dioxide (NO_2) and Nitrous oxide (N_2O). The formation of these oxides is due to mixing of Nitrogen and Oxygen gases. Although they occur naturally, they are also associated with anthropogenic activities with the primary source being the burning of fossil fuels. Its harmful effects include toxicity to plants, as well as acting as a secondary pollutant; mixing with primary pollutants with deleterious effects. The following comparisons show emissions for current (2015) and 5-year projection (2020).

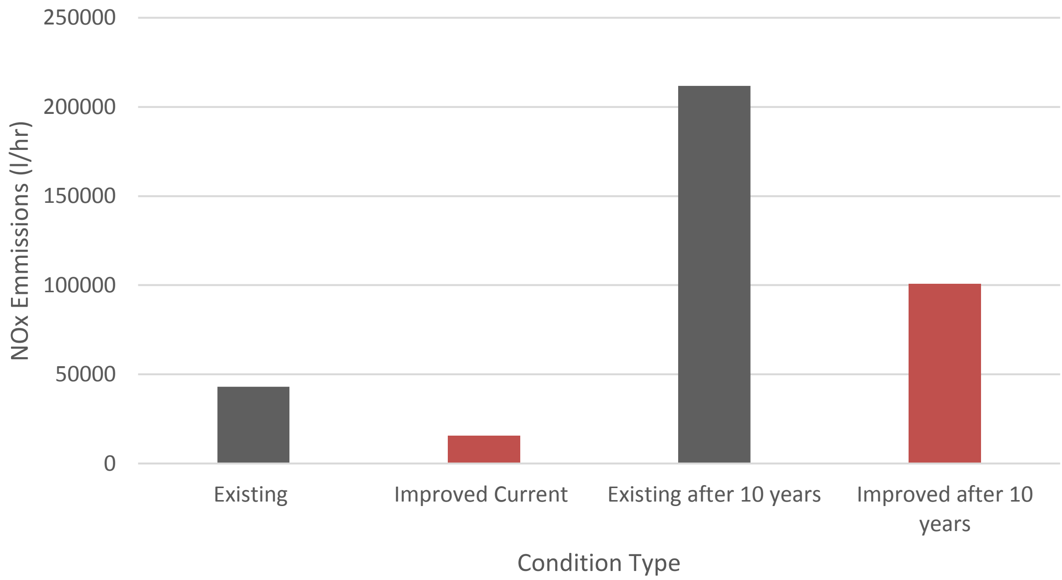

Figure 5.8 NO Emissions for Existing and Improved Conditions

5.9.3 Volatile Organic Compounds

Volatile organic compound is a substance containing carbon that evaporates at low temperatures. Examples include styrene, heptane and benzene among others. The burning of fossil fuel is also a contributor towards the emission of these VOC's into the environment. It causes smug and misty formations that make the air dense and difficult to breathe in with people having slight respiratory problems becoming more vulnerable to serious infections. The following comparisons show emissions for current (2015) and 5-year projection (2020).

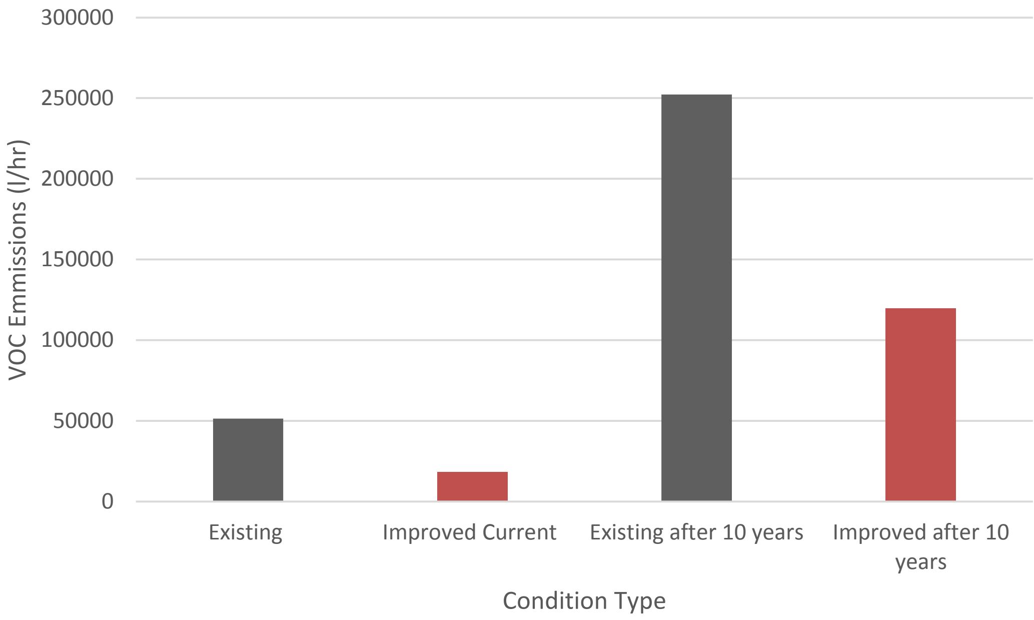

Figure 5.9 VOC emissions for existing and improved conditions

5.10 Summary

This chapter involves the infrastructure intervention technique used to improve the conditions both for existing year and for a projection of 5 years i.e. 2020. The existing traffic count was used to see the results and conditions after improvement. Then a comparison was drawn to see the impact of improvement.

Environmental Impact Assessment was carried out to see the economic as well as environmental impacts study. It was carried out for 4 conditions i.e. existing conditions before improvement for 2015, improved conditions 2015, existing conditions before improvement for 2020 and improved conditions 2020 and a comparison was drawn to see the effect of improvement.

Chapter 6

CONCLUSIONS

6.1 Summary of Findings

The Research was primarily aimed at studying the performance evaluation of at-grade urban signalized intersection. It includes the performance of existing condition and to know how we improve the existing conditions after optimization using the software synchro/simtraffic. This study help us to know how we can check the existing performance of at-grade urban signalized intersection and also how we optimize it to make it more efficient. This study not only helps us in the optimization of at-grade urban signalized intersections of Pakistan but the study also helps us outside the Pakistan. To optimize the existing signalized intersection it's very important to know the existing conditions. For this a field survey was carried so as to calculate the turning movement counts on our selected site. Here the selected site is Koral Chowk urban signalized intersection which is an at-grade signalized intersection. The field data was carried out on three different days of a week. According to HCM 2000 these days include the week day when the traffic is maximum, the weekend and the holiday. We select Tuesday, Friday and Sunday. Here we count the three hours traffic and turning movements' data which is also the peak hour of that day. After the data collection we have to find the peak hour of that day. As we get the peak hour of that particular day we have three peak hours one for Tuesday, one for Friday and one for Sunday. The one which is maximum of these three is the peak hour of that week. Once we got the peak hour of that week we have to find the PHF. Now we have the peak hour turning movement count along with the PHF. The analysis of results we obtained was carried out by using software synchro/simtraffic version 8.0. The synchro/simtraffic is a powerful analysis software which not only give us the existing capacity, saturation flow rate, level of service of all approaches and for whole intersection, intersection capacity utilization and its level of service, uniform delay, incremental delay and control delay and v/c ratio of all approaches, that are required for performance evaluation of at-grade signalized intersection. At the same time synchro/simtraffic optimize these above mention variables to make the signalized intersection more efficient.

After traffic analysis, the basic aim was to study the economic and social impacts of Koral chowk both for existing and improved conditions, both for 2015 and 2020.

6.2 Conclusions

Some conclusions and recommendations enlisted below are based on the research findings. These conclusions and recommendation will further help us for future solution so as to make the existing at-grade signalized intersection more efficient.

- The reliability of results produced by Synchro are dependent upon the geometric details and volumetric details of lanes and traffic respectively. Any kind of error in these will cause the results to be having errors and discrepancies.
- Increasing the green time for an approach improves its level of service, but, causes to increase the v/c ratio for other approaches.
- By optimization the ICU value does not change rather only signal timing and v/c ratio is changed.
- In our case, the level of service of some approaches changes but the overall LOS of the whole intersection remains the same.
- The results when simulated show that the lanes will carry only that traffic which will have the same direction as of lane.
- Increasing the number of lanes improves ICU and LOS.
- By improving the conditions, the social and economic impacts (negative) are reduced by almost 50%.

6.3 Future Recommendations

As the LOS of the whole intersection after optimization remains the same i.e. F, therefore the only solution is grade separation.

A grade separated facility i.e. a flyover carrying the EBR traffic will improve the existing conditions. Add one lane to EBT and WBT direction so that total number of lanes in EBT and WBT becomes 6. Provide an exclusive lane in all directions each having a curb radius of 150m. Provide 2 storage bays each of length 400m in EBL, WBL, WBR, and NBR direction. Provide one storage bay of length 400m in EBR direction. The EBL and WBL storage bays will accommodate for traffic turning in the specified directions.

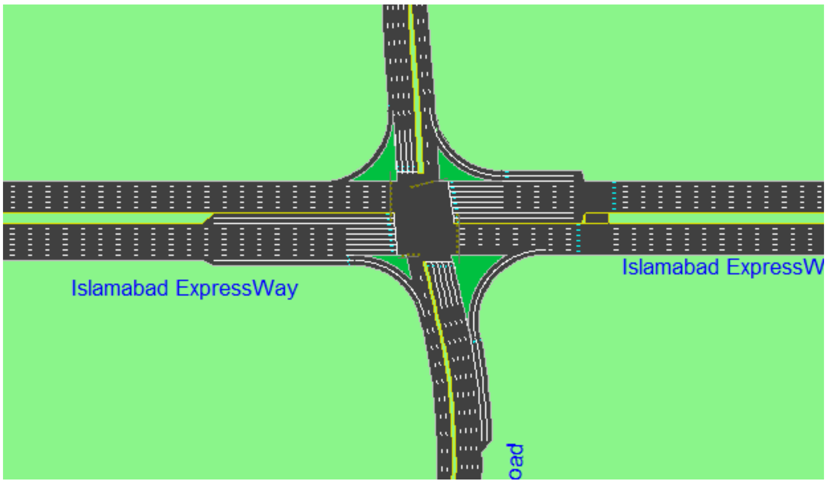

Figure 6.1 Proposed layout of Koral Chowk

Yellow time will be taken as 3.5 seconds. All red time is taken as 0.5 seconds. A total of 4 phases will be installed. The 1st phase will carry the EBL and WBL traffic having a total split of 32 seconds. The 2nd phase will carry the EBT and WBT traffic having a total split of 74 seconds. The 3rd phase will carry the NBT and NBL traffic having a total split of 60 seconds. And the 4th phase will carry the SBT and SBL having a total split of 34 seconds. The total cycle length in this way will be reduced from 306 seconds to 200 seconds.

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APPENDICES

APPENDIX A- THREE HOURS MORNING AND EVENING TRAFFIC COUNT SURVEY AT KORAL CHOWK, ISLAMABAD FOR PERFORMANCE EVALUATION OF AT GRADE SIGNALIZED INTERSECTION

Traffic Count on Friday 8am-11am

Date 06/03/2015 FRIDAY MORNING

Time	From North			From South			From West			From East			Interval Total	Hour Total
	Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right		
0800-0815	5	64	54	622	104	124	12	285	409	160	854	46	**2739**	
0815-0830	4	51	46	655	85	120	15	275	395	142	814	46	**2648**	
0830-0845	5	41	53	545	105	99	21	270	381	145	922	103	**2690**	
0845-0900	9	47	59	425	92	83	19	268	373	145	962	61	**2543**	**10620**
0900-0915	8	41	45	355	56	105	17	258	318	88	564	49	1904	9785
0915-0930	9	41	49	360	62	121	12	253	345	119	515	72	1958	9095
0930-0945	11	53	56	287	86	95	16	257	321	142	934	47	2305	8710
0945-1000	7	61	57	344	89	101	22	245	320	163	811	53	2273	8440
1000-1015	9	48	61	360	71	107	21	256	338	113	762	61	2207	8743
1015-1030	8	59	59	283	90	68	18	271	322	102	615	160	2055	8840
1030-1045	7	57	55	343	89	98	18	262	312	139	536	128	2044	8579
1045-1100	9	52	49	360	81	124	15	232	323	117	531	114	2007	8313
Total	**91**	**615**	**643**	**4939**	**1010**	**1245**	**206**	**3132**	**4157**	**1575**	**8820**	**940**	**27373**	

Peak hour Volume Friday Morning

Date 06/03/2015 **FRIDAY MORNING**

Time	From North			From South			From West			From East			Interval Total
	Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right	
0800-0900	23	203	212	2247	386	426	67	1098	1558	592	3552	256	**10620**
0815-0915	26	180	203	1980	338	407	72	1071	1467	520	3262	259	9785
0830-0930	31	170	206	1685	315	408	69	1049	1417	497	2963	285	9095
0845-0945	37	182	209	1427	296	404	64	1036	1357	494	2975	229	8710
0900-1000	35	196	207	1346	293	422	67	1013	1304	512	2824	221	8440
0915-1015	36	203	223	1351	308	424	71	1011	1324	537	3022	233	8743
0930-1030	35	221	233	1274	336	371	77	1029	1301	520	3122	321	8840
0945-1045	31	225	232	1330	339	374	79	1034	1292	517	2724	402	8579
1000-1100	33	216	224	1346	331	397	72	1021	1295	471	2444	463	8313

Traffic Count on Friday 4pm-7pm

Date 06/03/2015 **FRIDAY EVENING**

Time	From North			From South			From West			From East			Interval Total	Hour Total
	Left	**Through**	**Right**	**Left**	**Through**	**Right**	**Left**	**Through**	**Right**	**Left**	**Through**	**Right**		
0400-0415	7	42	41	443	67	142	44	788	342	87	279	25	2307	
0415-0430	6	39	34	403	55	137	37	636	326	69	315	19	2076	
0430-0445	4	39	37	421	68	152	43	554	269	48	326	20	1981	
0445-0500	7	37	40	407	59	158	48	551	342	75	308	24	2056	8420
0500-0515	11	33	38	368	36	103	36	584	327	71	294	21	1922	8035
0515-0530	8	31	39	402	40	117	41	533	273	67	309	30	1890	7849
0530-0545	13	40	42	379	56	156	45	967	404	85	322	27	**2536**	8404
0545-0600	8	41	44	384	57	153	46	841	532	74	325	21	**2526**	8874
0600-0615	7	39	47	391	46	141	49	884	668	59	331	27	**2689**	9641
0615-0630	12	38	39	378	58	89	47	843	639	70	342	21	**2576**	**10327**
0630-0645	4	41	36	363	57	159	44	955	347	84	303	32	2425	10216
0645-0700	3	43	43	371	52	101	37	996	368	89	310	34	2447	10137
Total	**90**	**463**	**480**	**4710**	**651**	**1608**	**517**	**9132**	**4837**	**878**	**3764**	**301**	**27431**	

Peak Hour Volume Friday Evening

Date 06/03/2015 FRIDAY EVENING

Time	From North			From South			From West			From East			Interval Total
	Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right	
0400-0500	24	157	152	1674	249	589	172	2529	1279	279	1228	88	8420
0415-0515	28	148	149	1599	218	550	164	2325	1264	263	1243	84	8035
0430-0530	30	140	154	1598	203	530	168	2222	1211	261	1237	95	7849
0445-0545	39	141	159	1556	191	534	170	2635	1346	298	1233	102	8404
0500-0600	40	145	163	1533	189	529	168	2925	1536	297	1250	99	8874
0515-0615	36	151	172	1556	199	567	181	3225	1877	285	1287	105	9641
0530-0630	40	158	172	1532	217	539	187	3535	2243	288	1320	96	**10327**
0545-0645	31	159	166	1516	218	542	186	3523	2186	287	1301	101	10216
0600-0700	26	161	165	1503	213	490	177	3678	2022	302	1286	114	10137

Traffic Count on Sunday 8am-11am

Date 08/03/2015 **SUNDAY MORNING**

Time	From North			From South			From West			From East			Interval Total	Hour Total
	Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right		
0800-0815	4	62	22	249	40	51	8	117	164	64	342	37	1160	
0815-0830	6	54	19	262	33	48	7	110	158	57	326	37	1117	
0830-0845	5	44	22	218	44	41	11	108	152	58	369	43	1115	
0845-0900	9	41	24	170	35	33	12	108	149	58	385	49	1073	4465
0900-0915	8	51	18	142	22	42	11	104	127	35	226	39	825	4130
0915-0930	10	56	32	144	62	48	14	101	138	48	206	58	917	3930
0930-0945	8	59	54	115	69	57	18	155	129	85	560	38	**1347**	4162
0945-1000	9	64	55	138	72	61	26	147	192	97	487	43	**1391**	4480
1000-1015	11	58	67	145	69	65	28	154	203	68	458	49	**1375**	5030
1015-1030	20	67	65	114	68	41	24	163	193	61	369	128	**1313**	**5426**
1030-1045	18	66	61	138	64	40	18	105	125	4	322	103	1064	5143
1045-1100	17	48	54	142	65	51	15	93	129	46	319	92	1071	4823
Total	**125**	**670**	**493**	**1977**	**643**	**578**	**192**	**1465**	**1859**	**681**	**4369**	**716**	**13768**	

Peak Hour Volume Sunday Morning

Date 08/03/2015 **SUNDAY MORNING**

Time	From North			From South			From West			From East			Interval Total
	Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right	
0400-0500	24	201	87	899	152	173	38	443	623	237	1422	166	4465
0415-0515	28	190	83	792	134	164	41	430	586	208	1306	168	4130
0430-0530	32	192	96	674	163	164	48	421	566	199	1186	189	3930
0445-0545	35	207	128	571	188	180	55	468	543	226	1377	184	4162
0500-0600	35	230	159	539	225	208	69	507	586	265	1479	178	4480
0515-0615	38	237	208	542	272	231	86	557	662	298	1711	188	5030
0530-0630	48	248	241	512	278	224	96	619	717	311	1874	258	**5426**
0545-0645	58	255	248	535	273	207	96	569	713	230	1636	323	5143
0600-0700	66	239	247	539	266	197	85	515	650	179	1468	372	4823

Traffic Count on Sunday 4pm-7pm

Date 08/03/2015 **SUNDAY EVENING**

Time	From North			From South			From West			From East			Interval Total	Hour Total
	Left	**Through**	**Right**	**Left**	**Through**	**Right**	**Left**	**Through**	**Right**	**Left**	**Through**	**Right**		
0400-0415	6	81	28	324	52	66	10	152	213	83	445	48	1508	
0415-0430	8	71	25	341	43	63	9	143	205	74	424	49	1455	
0430-0445	7	57	29	283	57	53	14	140	198	75	480	56	1449	
0445-0500	12	54	32	221	45	43	15	139	193	74	501	64	1393	5805
0500-0515	12	66	24	185	29	54	14	135	165	46	294	51	1075	5372
0515-0530	15	99	48	216	93	72	21	152	207	72	309	87	1391	5308
0530-0545	12	89	81	173	103	86	27	233	194	128	840	57	**2023**	5882
0545-0600	14	96	83	207	108	92	39	221	288	146	730	65	**2089**	6578
0600-0615	17	87	101	217	104	98	42	231	305	102	687	74	**2065**	7568
0615-0630	30	87	85	148	88	53	31	212	251	79	479	166	**1709**	**7886**
0630-0645	24	86	79	179	83	52	23	137	163	109	418	134	1487	7350
0645-0700	22	62	70	184	84	66	19	121	167	59	415	121	1390	6651
Total	**179**	**935**	**685**	**2678**	**889**	**798**	**264**	**2016**	**2549**	**1047**	**6022**	**972**	**19034**	

Peak Hour Volume Sunday Evening

<u>**Date 08/03/2015**</u> **SUNDAY EVENING**

Time	From North			From South			From West			From East			Interval Total
	Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right	
0400-0500	33	263	114	1169	197	225	48	574	809	306	1850	217	5805
0415-0515	39	248	110	1030	174	213	52	557	761	269	1699	220	5372
0430-0530	46	276	133	905	224	222	64	566	763	267	1584	258	5308
0445-0545	51	308	185	795	270	255	77	659	759	320	1944	259	5882
0500-0600	53	350	236	781	333	304	101	741	854	392	2173	260	6578
0515-0615	58	371	313	813	408	348	129	837	994	448	2566	283	7568
0530-0630	73	359	350	745	403	329	139	897	1038	455	2736	362	**7886**
0545-0645	85	356	348	751	383	295	135	801	1007	436	2314	439	7350
0600-0700	93	322	335	728	359	269	115	701	886	349	1999	495	6651

Traffic Count on Tuesday 8am-11am

Date 08/03/2015 **TUESDAY MORNING**

Time	From North			From South			From West			From East			Interval Total	Hour Total
	Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right		
0400-0415	9	116	70	809	135	161	16	371	532	208	1109	61	3597	
0415-0430	9	106	69	982	127	180	23	413	593	213	1221	69	4005	
0430-0445	11	85	81	817	158	149	32	405	572	218	1283	154	3965	
0445-0500	19	99	88	637	138	151	29	397	559	217	1173	121	3628	15195
0500-0515	24	91	79	653	78	147	24	404	589	198	1184	145	3616	15214
0515-0530	18	81	68	504	87	169	17	354	483	167	721	101	2770	13979
0530-0545	21	104	78	402	121	133	23	361	449	199	1307	66	**3264**	13278
0545-0600	14	119	79	481	124	141	31	343	448	228	1135	74	**3217**	12867
0600-0615	18	94	85	504	99	149	29	358	473	158	1067	85	**3119**	12370
0615-0630	17	116	83	396	126	95	25	379	451	143	861	224	**2916**	**12516**
0630-0645	14	106	72	446	116	127	23	340	406	181	697	167	2695	11947
0645-0700	18	92	68	440	109	161	24	265	420	152	743	137	2629	11359
Total	**192**	**1209**	**920**	**7071**	**1418**	**1763**	**296**	**4390**	**5975**	**2282**	**12501**	**1402**	**39421**	

Peak Hour Volume Tuesday Morning

Date 08/03/2015 TUESDAY MORNING

Time	From North			From South			From West			From East			Interval Total
	Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right	
0400-0500	48	406	308	3245	558	641	100	1586	2256	856	4786	405	15195
0415-0515	63	381	317	3089	501	627	108	1619	2313	846	4861	489	15214
0430-0530	72	356	316	2611	461	616	102	1560	2203	800	4361	521	13979
0445-0545	82	375	313	2196	424	600	93	1516	2080	781	4385	433	13278
0500-0600	77	395	304	2040	410	590	95	1462	1969	792	4347	386	12867
0515-0615	71	398	310	1891	431	592	100	1416	1853	752	4230	326	12370
0530-0630	70	433	325	1783	470	518	108	1441	1821	728	4370	449	**12516**
0545-0645	63	435	319	1827	465	512	108	1420	1778	710	3760	550	11947
0600-0700	67	408	308	1786	450	532	101	1342	1750	634	3368	613	11359

Traffic Count on Tuesday 4pm-11pm

Date 08/03/2015 **TUESDAY EVENING**

Time	From North			From South			From West			From East			Interval Total	Hour Total
	Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right		
0400-0415	11	67	66	709	107	227	71	1261	549	139	446	40	3693	
0415-0430	10	62	54	645	88	219	59	1017	522	111	504	31	3322	
0430-0445	7	62	59	674	109	243	69	887	431	103	522	32	3198	
0445-0500	12	59	64	651	95	253	77	945	547	121	493	38	3355	5805
0500-0515	21	78	78	713	89	286	78	1288	707	148	603	62	4151	5372
0515-0530	15	56	70	723	72	231	73	1371	650	121	556	54	3992	5308
0530-0545	23	72	76	682	100	281	82	1654	818	154	583	52	**4577**	5882
0545-0600	15	75	79	692	103	276	83	1513	858	136	585	42	**4457**	6578
0600-0615	12	63	75	626	74	226	78	1213	920	95	487	24	**3893**	7568
0615-0630	19	61	62	604	93	142	75	1348	988	112	547	33	**4084**	**7886**
0630-0645	7	66	57	581	91	254	71	1277	555	134	484	51	3628	7350
0645-0700	6	68	68	593	83	162	59	1204	588	143	497	55	3526	6651
Total	**158**	**789**	**808 2**	**7893**	**1104**	**2800**	**875**	**14978**	**8133**	**1517**	**6307**	**514**	**45876**	

Peak Hour Volume Tuesday Evening

Date 08/03/2015 **TUESDAY EVENING**

Time	From North			From South			From West			From East			Interval Total
	Left	**Through**	**Right**	**Left**	**Through**	**Right**	**Left**	**Through**	**Right**	**Left**	**Through**	**Right**	
0400-0500	40	250	243	2679	399	942	276	4110	2049	474	1965	141	13568
0415-0515	3950	261	255	2683	381	1001	283	4137	2207	483	2122	163	14026
0430-0530	55	255	271	2761	365	1013	297	4491	2335	493	2174	186	14696
0445-0545	71	265	288	2769	356	1051	310	5258	2722	544	2235	206	16075
0500-0600	74	281	303	2810	364	1074	316	5826	3033	559	2327	210	17177
0515-0615	65	266	300	2723	349	1014	316	5751	3246	506	2211	172	16919
0530-0630	69	271	292	2604	370	925	318	5728	3584	497	2202	151	**17011**
0545-0645	53	265	273	2503	361	898	307	5351	3321	477	2103	150	16062
0600-0700	44	258	262	2404	341	784	283	5042	3051	484	2015	163	15131

Peak Hour Factor Friday

<u>Date 06/03/2015</u> **FRIDAY PEAK HOUR FACTOR**

Time	From North			From South			From West			From East			Interval Total
	Left	**Through**	**Right**	**Left**	**Through**	**Right**	**Left**	**Through**	**Right**	**Left**	**Through**	**Right**	
0530-0545	13	40	42	379	56	156	45	967	404	85	322	27	**2536**
0545-0600	8	41	44	384	57	153	46	841	532	74	325	21	**2526**
0600-0615	7	39	47	391	46	141	49	884	668	59	331	27	**2689**
0615-0630	12	38	39	378	58	89	47	843	639	70	342	21	**2576**
Total	40	158	172	1532	217	539	187	3535	2243	288	1320	96	**10327**
PHF	0.769	0.963	0.915	0.979	0.935	0.863	0.954	0.914	0.839	0.847	0.965	0.89	0.96

Peak Hour Factor Sunday

Date 08/03/2015 **SUNDAY PEAK HOUR FACTOR**

Time	From North			From South			From West			From East			Interval Total
	Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right	
0530-0545	12	89	81	173	103	86	27	233	194	128	840	57	**2023**
0545-0600	14	96	83	207	108	92	39	221	288	146	730	65	**2089**
0600-0615	17	87	101	217	104	98	42	231	305	102	687	74	**2065**
0615-0630	30	87	85	148	88	53	31	212	251	79	479	166	**1709**
Total	73	359	350	745	403	329	139	897	1038	455	2736	362	**7886**
PHF	0.608	0.934	0.866	0.858	0.933	0.839	0.827	0.962	0.85	0.779	0.814	0.545	0.943

Peak Hour Factor Tuesday

Date 08/03/2015 **TUESDAY PEAK HOUR FACTOR**

Time	From North			From South			From West			From East			Interval Total
	Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right	
0500-0515	21	78	78	713	89	286	78	1288	707	148	603	62	**4151**
0515-0530	15	56	70	723	72	231	73	1371	650	121	556	54	**3992**
0530-0545	23	72	76	682	100	281	82	1654	818	154	583	52	**4577**
0545-0600	15	75	79	692	103	276	83	1513	858	136	585	42	**4457**
Total	74	281	303	2810	364	1074	316	5826	3033	559	2327	210	**17177**
PHF	0.804	0.9	0.958	0.971	0.883	0.938	0.951	0.88	0.884	0.907	0.965	0.847	0.938

APPENDIX B-SYNCHRO REPORTS BEFORE OPTIMIZATION FOR EXISTING CONDITIONS IN 2015

Performance Evaluation of Koral

3: Airport Road/Koral Road & Islamabad ExpressWay 4/21/2015

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	74	2327	2810	559	5826	303	3033	281	1074	210	364	316
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Storage Length (ft)	0		400	400		250	50		400	250		250
Storage Lanes	1		2	0		0	0		2	0		0
Taper Length (ft)	25			25			25			25		
Lane Util. Factor	*1.00	*0.86	*0.88	*1.00	*0.86	*1.00	0.91	*1.00	*1.00	*1.00	0.95	*1.00
Frt		*0.950	0.850		*0.850	0.850	*0.950	*0.950	0.850		*0.950	0.850
Flt Protected	0.950	*0.850	*0.950		*0.850		*0.850	*0.850	*0.950		*0.850	
Satd. Flow (prot)	1770	5174	2647	0	4630	1583	2738	1504	3008	0	2858	1583
Flt Permitted	0.950				0.713		0.850	0.850			0.850	
Satd. Flow (perm)	1770	6087	2787	0	3883	1583	2738	1504	3167	0	2858	1583
Right Turn on Red			Yes			No			No			No
Satd. Flow (RTOR)			353									
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		1000			400			1002			1009	
Travel Time (s)		22.7			9.1			22.7			22.7	
Peak Hour Factor	0.95	0.88	0.88	0.91	0.96	0.85	0.97	0.88	0.94	0.80	0.90	0.96
Adj. Flow (vph)	78	2644	3193	614	6069	356	3127	319	1143	262	404	329
Shared Lane Traffic (%)							27%					
Lane Group Flow (vph)	78	2644	3193	0	6683	356	2283	1163	1143	0	666	329
Enter Blocked Intersection	No	No	No	No	No	No	No	No	No	No	No	No
Lane Alignment	Left	Left	Right	Left	Left	Right	Left	Left	Right	Left	Left	Right
Median Width(ft)		12			12			30			0	
Link Offset(ft)		0			0			0			0	
Crosswalk Width(ft)		16			16			16			16	
Two way Left Turn Lane												
Headway Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Turning Speed (mph)	15		9	15		9	15		9	15		9
Turn Type	Split	NA	Perm	Split	NA	Perm	Split	NA	Prot	Split	NA	Perm
Protected Phases	2	2		3	3		4	4!	4	1	1	
Permitted Phases			2		4!	3						1
Minimum Split (s)	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Total Split (s)	104.0	104.0	104.0	104.0	104.0	104.0	64.0	64.0	64.0	34.0	34.0	34.0

FYP 5:00 pm 4/6/2015 Baseline
Faisal Raza

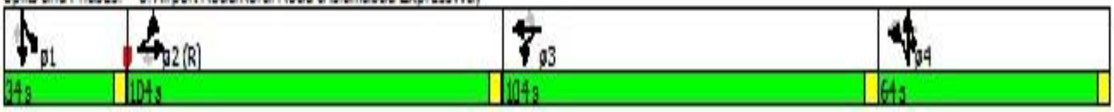
Synchro 8 Report
Page 1

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Total Split (%)	34.0%	34.0%	34.0%	34.0%	34.0%	34.0%	20.9%	20.9%	20.9%	11.1%	11.1%	11.1%
Maximum Green (s)	100.0	100.0	100.0	100.0	100.0	100.0	60.0	60.0	60.0	30.0	30.0	30.0
Yellow Time (s)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
All-Red Time (s)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Lost Time Adjust (s)	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0
Total Lost Time (s)	4.0	4.0	4.0		4.0	4.0	4.0	4.0	4.0		4.0	4.0
Lead/Lag	Lag	Lag	Lag	Lead	Lead	Lead	Lag	Lag	Lag	Lead	Lead	Lead
Lead-Lag Optimize?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Act Effct Green (s)	100.0	100.0	100.0		160.0	100.0	60.0	60.0	60.0		30.0	30.0
Actuated g/C Ratio	0.33	0.33	0.33		0.52	0.33	0.20	0.20	0.20		0.10	0.10
v/c Ratio	0.13	1.56	2.78		2.94	0.69	4.26	3.96	1.94		2.38	2.12
Control Delay	73.4	312.8	827.1		894.9	97.6	1488.6	1357.4	477.1		670.3	571.8
Queue Delay	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0
Total Delay	73.4	312.8	827.1		894.9	97.6	1488.6	1357.4	477.1		670.3	571.8
LOS	E	F	F		F	F	F	F	F		F	F
Approach Delay		587.3			854.6			1203.4			637.7	
Approach LOS		F			F			F			F	

Intersection Summary

Area Type: Other
Cycle Length: 306
Actuated Cycle Length: 306
Offset: 0 (0%), Referenced to phase 2:EBTL, Start of Green
Natural Cycle: 140
Control Type: Pretimed
Maximum v/c Ratio: 4.26
Intersection Signal Delay: 844.0 Intersection LOS: F
Intersection Capacity Utilization 217.4% ICU Level of Service H
Analysis Period (min) 15
Description: FYP
* User Entered Value
! Phase conflict between lane groups.

Splits and Phases: 3: Airport Road/Koral Road & Islamabad ExpressWay



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width (ft)	12	12	12	12	12	12	12	12	12	12	12	12
Grade (%)		0%			0%			0%			0%	
Storage Length (ft)	0		400	400		250	50		400	250		250
Storage Lanes	1		2	0		0	0		2	0		0
Taper Length (ft)	25			25			25			25		
Lane Util. Factor	*1.00	*0.86	*0.88	*1.00	*0.86	*1.00	0.91	*1.00	*1.00	*1.00	0.95	*1.00
Ped Bike Factor												
Frt		*0.950	0.850		*0.850	0.850	*0.950	*0.950	0.850		*0.950	0.850
Flt Protected	0.950	*0.850	*0.950		*0.850		*0.850	*0.850	*0.950		*0.850	
Satd. Flow (prot)	1770	5174	2647	0	4630	1583	2738	1504	3008	0	2858	1583
Flt Permitted	0.950				0.713		0.850	0.850			0.850	
Satd. Flow (perm)	1770	6087	2787	0	3883	1583	2738	1504	3167	0	2858	1583
Right Turn on Red			Yes			No			No			No
Satd. Flow (RTOR)			353									
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		1000			400			1002			1009	
Travel Time (s)		22.7			9.1			22.7			22.7	

Intersection Summary	
Area Type:	Other
Description: FYP	

* User Entered Value

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Volume (vph)	74	2327	2810	559	5826	303	3033	281	1074	210	364	316
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.95	0.88	0.88	0.91	0.96	0.85	0.97	0.88	0.94	0.80	0.90	0.96
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Adj. Flow (vph)	78	2644	3193	614	6069	356	3127	319	1143	262	404	329
Shared Lane Traffic (%)							27%					
Lane Group Flow (vph)	78	2644	3193	0	6683	356	2283	1163	1143	0	666	329

Intersection Summary
Description: FYP

Lane Group	EBL	EBT	EBR	WBT	WBR	NBL	NBT	NBR	SBT	SBR
Lane Configurations										
Volume (vph)	74	2327	2810	5826	303	3033	281	1074	364	316
Turn Type	Split	NA	Perm	NA	Perm	Split	NA	Prot	NA	Perm
Protected Phases	2	2		3		4	4!	4	1	
Permitted Phases			2	4!	3					1
Detector Phase	2	2	2	3	3	4	4	4	1	1
Switch Phase										
Minimum Initial (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Minimum Split (s)	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Total Split (s)	104.0	104.0	104.0	104.0	104.0	64.0	64.0	64.0	34.0	34.0
Total Split (%)	34.0%	34.0%	34.0%	34.0%	34.0%	20.9%	20.9%	20.9%	11.1%	11.1%
Yellow Time (s)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
All-Red Time (s)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Lead/Lag	Lag	Lag	Lag	Lead	Lead	Lag	Lag	Lag	Lead	Lead
Lead-Lag Optimize?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Recall Mode	Max	Max	Max	Max	Max	Max	Max	Max	Max	Max
Act Effct Green (s)	100.0	100.0	100.0	160.0	100.0	60.0	60.0	60.0	30.0	30.0
Actuated g/C Ratio	0.33	0.33	0.33	0.52	0.33	0.20	0.20	0.20	0.10	0.10
v/c Ratio	0.13	1.56	2.78	2.94	0.69	4.26	3.96	1.94	2.38	2.12
Control Delay	73.4	312.8	827.1	894.9	97.6	1488.6	1357.4	477.1	670.3	571.8
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	73.4	312.8	827.1	894.9	97.6	1488.6	1357.4	477.1	670.3	571.8
LOS	E	F	F	F	F	F	F	F	F	F
Approach Delay		587.3		854.6			1203.4		637.7	
Approach LOS		F		F			F		F	

Intersection Summary

Cycle Length: 306

Actuated Cycle Length: 306

Offset: 0 (0%), Referenced to phase 2:EBTL, Start of Green

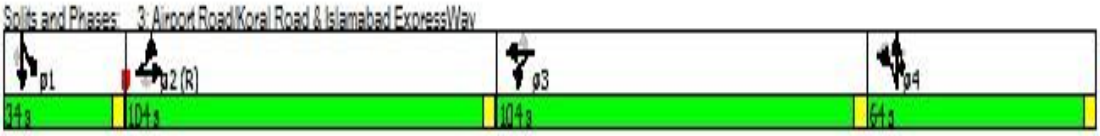
Natural Cycle: 140

Control Type: Pretimed

Maximum v/c Ratio: 4.26	
Intersection Signal Delay: 844.0	Intersection LOS: F
Intersection Capacity Utilization 217.4%	ICU Level of Service H
Analysis Period (min) 15	
Description: FYP	

! Phase conflict between lane groups.

Splits and Phases: 3: Airport Road/Koral Road & Islamabad ExpressWay



Lane Group	EBL	EBT	EBR	WBT	WBR	NBL	NBT	NBR	SBT	SBR
Protected Phases	2	2		3		4	4!	4	1	
Permitted Phases			2	4!	3					1
Minimum Initial (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Minimum Split (s)	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Total Split (s)	104.0	104.0	104.0	104.0	104.0	64.0	64.0	64.0	34.0	34.0
Total Split (%)	34.0%	34.0%	34.0%	34.0%	34.0%	20.9%	20.9%	20.9%	11.1%	11.1%
Maximum Green (s)	100.0	100.0	100.0	100.0	100.0	60.0	60.0	60.0	30.0	30.0
Yellow Time (s)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
All-Red Time (s)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Lead/Lag	Lag	Lag	Lag	Lead	Lead	Lag	Lag	Lag	Lead	Lead
Lead-Lag Optimize?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Vehicle Extension (s)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Minimum Gap (s)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Time Before Reduce (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Time To Reduce (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Recall Mode	Max	Max	Max	Max	Max	Max	Max	Max	Max	Max
Walk Time (s)										
Flash Dont Walk (s)										
Pedestrian Calls (#/hr)										
90th %ile Green (s)	100.0	100.0	100.0	100.0	100.0	60.0	60.0	60.0	30.0	30.0
90th %ile Term Code	Coord	Coord	Coord	MaxR	MaxR	MaxR	MaxR	MaxR	MaxR	MaxR
70th %ile Green (s)	100.0	100.0	100.0	100.0	100.0	60.0	60.0	60.0	30.0	30.0
70th %ile Term Code	Coord	Coord	Coord	MaxR	MaxR	MaxR	MaxR	MaxR	MaxR	MaxR
50th %ile Green (s)	100.0	100.0	100.0	100.0	100.0	60.0	60.0	60.0	30.0	30.0
50th %ile Term Code	Coord	Coord	Coord	MaxR	MaxR	MaxR	MaxR	MaxR	MaxR	MaxR
30th %ile Green (s)	100.0	100.0	100.0	100.0	100.0	60.0	60.0	60.0	30.0	30.0
30th %ile Term Code	Coord	Coord	Coord	MaxR	MaxR	MaxR	MaxR	MaxR	MaxR	MaxR
10th %ile Green (s)	100.0	100.0	100.0	100.0	100.0	60.0	60.0	60.0	30.0	30.0
10th %ile Term Code	Coord	Coord	Coord	MaxR	MaxR	MaxR	MaxR	MaxR	MaxR	MaxR

Intersection Summary

Cycle Length: 306

Actuated Cycle Length: 306

Offset: 0 (0%), Referenced to phase 2:EBTL, Start of Green

Control Type: Pretimed

Description: FYP

! Phase conflict between lane groups.

Lane Group	EBL	EBT	EBR	WBT	WBR	NBL	NBT	NBR	SBT	SBR
Lane Group Flow (vph)	78	2644	3193	6683	356	2283	1163	1143	666	329
v/c Ratio	0.13	1.56	2.78	2.94	0.69	4.26	3.96	1.94	2.38	2.12
Control Delay	73.4	312.8	827.1	894.9	97.6	1488.6	1357.4	477.1	670.3	571.8
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	73.4	312.8	827.1	894.9	97.6	1488.6	1357.4	477.1	670.3	571.8
Queue Length 50th (ft)	113	~2193	~5986	~6763	638	~4643	~4260	~1779	~1161	~1055
Queue Length 95th (ft)	171	#2117	#5742	#6454	726	#4678	#4382	#1900	#1304	#1302
Internal Link Dist (ft)		920		320			922		929	
Turn Bay Length (ft)			400		250	50		400		250
Base Capacity (vph)	578	1690	1148	2274	517	536	294	589	280	155
Starvation Cap Reductn	0	0	0	0	0	0	0	0	0	0
Spillback Cap Reductn	0	0	0	0	0	0	0	0	0	0
Storage Cap Reductn	0	0	0	0	0	0	0	0	0	0
Reduced v/c Ratio	0.13	1.56	2.78	2.94	0.69	4.26	3.96	1.94	2.38	2.12

Intersection Summary

Description: FYP

~ Volume exceeds capacity, queue is theoretically infinite.
Queue shown is maximum after two cycles.

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Enter Blocked Intersection	No	No	No	No	No	No	No	No	No	No	No	No
Lane Alignment	Left	Left	Right	Left	Left	Right	Left	Left	Right	Left	Left	Right
Median Width(ft)		12			12			30			0	
Link Offset(ft)		0			0			0			0	
Crosswalk Width(ft)		16			16			16			16	
Two way Left Turn Lane												
Headway Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Turning Speed (mph)	15		9	15		9	15		9	15		9

Intersection Summary
Description: FYP

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	74	2327	2810	559	5826	303	3033	281	1074	210	364	316
Pedestrians												
Ped Button												
Pedestrian Timing (s)												
Free Right			No			No			No			No
Ideal Flow	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lost Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Minimum Green (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Refr Cycle Length (s)	120	120	120	120	120	120	120	120	120	120	120	120
Volume Combined (vph)	74	2327	2810	0	6385	303	0	3314	1074	0	574	316
Lane Utilization Factor	1.00	0.91	0.89	1.00	0.91	1.00	0.97	1.00	0.89	1.00	0.95	1.00
Turning Factor (vph)	0.95	1.00	0.85	0.95	1.00	0.85	0.95	0.95	0.85	0.95	0.98	0.85
Saturated Flow (vph)	1805	6901	2859	0	6871	1615	0	5439	2859	0	3551	1615
Ped Intf Time (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pedestrian Frequency (%)		0.00			0.00			0.00			0.00	
Protected Option Allowed		No			No			No			No	
Reference Time (s)			118.0			22.5			45.1			23.5
Adj Reference Time (s)			122.0			26.5			49.1			27.5
Permitted Option												
Adj Saturation A (vph)	120	1725		0	115		0	384		0	118	
Reference Time A (s)	73.8	40.5		0.0	585.8		0.0	1034.3		0.0	212.9	
Adj Saturation B (vph	NA	NA		NA	NA		NA	NA		NA	NA	
Reference Time B (s)	NA	NA		NA	NA		NA	NA		NA	NA	
Reference Time (s)		73.8			585.8			1034.3			212.9	
Adj Reference Time (s)		77.8			589.8			1038.3			216.9	
Split Option												
Ref Time Combined (s)	4.9	40.5		0.0	111.5		0.0	73.1		0.0	19.4	
Ref Time Seperate (s)	4.9	40.5		37.2	101.3		69.2	17.7		14.0	12.1	
Reference Time (s)	40.5	40.5		111.5	111.5		73.1	73.1		19.4	19.4	
Adj Reference Time (s)	44.5	44.5		115.5	115.5		77.1	77.1		23.4	23.4	

Summary	EB WB		NB SB		Combined
Protected Option (s)	NA		NA		

Permitted Option (s)	589.8		1038.3		
Split Option (s)	160.0		100.5		
Minimum (s)	160.0		100.5		260.5

Right Turns	EBR	WBR	NBR	SBR
Adj Reference Time (s)	122.0	26.5	49.1	27.5
Cross Thru Ref Time (s)	23.4	77.1	44.5	115.5
Oncoming Left Ref Time (s)	115.5	44.5	23.4	77.1
Combined (s)	260.9	148.1	116.9	220.1

Intersection Summary			
Intersection Capacity Utilization	217.4%	ICU Level of Service	H

Reference Times and Phasing Options do not represent an optimized timing plan.

APPENDIX C- SYNCHRO REPORTS AFTER OPTIMIZATION FOR EXISTING CONDITIONS IN 2015

Performance Evaluation of Koral

3: Airport Road/Koral Road & Islamabad ExpressWay 4/21/2015

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	74	2327	2810	559	5826	303	3033	281	1074	210	364	316
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Storage Length (ft)	0		400	400		250	50		400	250		250
Storage Lanes	1		2	0		0	0		2	0		0
Taper Length (ft)	25			25			25			25		
Lane Util. Factor	*1.00	*0.86	*0.88	*1.00	*0.86	*1.00	0.91	*1.00	*1.00	*1.00	0.95	*1.00
Frt		*0.950	0.850		*0.850	0.850	*0.950	*0.950	0.850		*0.950	0.850
Flt Protected	0.950	*0.850	*0.950		*0.850		*0.850	*0.850	*0.950		*0.850	
Satd. Flow (prot)	1770	5174	2647	0	4630	1583	2738	1504	3008	0	2858	1583
Flt Permitted	0.950	0.850			0.707		0.850	0.850			0.850	
Satd. Flow (perm)	1770	5174	2787	0	3851	1583	2738	1504	3167	0	2858	1583
Right Turn on Red			Yes			No			No			No
Satd. Flow (RTOR)			395									
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		1000			400			1002			1009	
Travel Time (s)		22.7			9.1			22.7			22.7	
Peak Hour Factor	0.95	0.88	0.88	0.91	0.96	0.85	0.97	0.88	0.94	0.80	0.90	0.96
Adj. Flow (vph)	78	2644	3193	614	6069	356	3127	319	1143	262	404	329
Shared Lane Traffic (%)	10%						27%					
Lane Group Flow (vph)	70	2652	3193	0	6683	356	2283	1163	1143	0	666	329
Enter Blocked Intersection	No	No	No	No	No	No	No	No	No	No	No	No
Lane Alignment	Left	Left	Right	Left	Left	Right	Left	Left	Right	Left	Left	Right
Median Width(ft)		12			12			30			0	
Link Offset(ft)		0			0			0			0	
Crosswalk Width(ft)		16			16			16			16	
Two way Left Turn Lane												
Headway Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Turning Speed (mph)	15		9	15		9	15		9	15		9
Turn Type	Split	NA	Perm	Split	NA	Perm	Split	NA	Prot	Split	NA	Perm
Protected Phases	2	2		3	3		4	4!	4	1	1	
Permitted Phases			2		4!	3						1
Minimum Split (s)	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Total Split (s)	96.0	96.0	96.0	82.0	82.0	82.0	92.0	92.0	92.0	30.0	30.0	30.0
Total Split (%)	32.0%	32.0%	32.0%	27.3%	27.3%	27.3%	30.7%	30.7%	30.7%	10.0%	10.0%	10.0%
Maximum Green (s)	92.0	92.0	92.0	78.0	78.0	78.0	88.0	88.0	88.0	26.0	26.0	26.0
Yellow Time (s)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
All-Red Time (s)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Lost Time Adjust (s)	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0
Total Lost Time (s)	4.0	4.0	4.0		4.0	4.0	4.0	4.0	4.0		4.0	4.0
Lead/Lag	Lag	Lag	Lag	Lead	Lead	Lead	Lag	Lag	Lag	Lead	Lead	Lead
Lead-Lag Optimize?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Act Effct Green (s)	92.0	92.0	92.0		166.0	78.0	88.0	88.0	88.0		26.0	26.0
Actuated g/C Ratio	0.31	0.31	0.31		0.55	0.26	0.29	0.29	0.29		0.09	0.09
v/c Ratio	0.13	1.67	2.83		2.86	0.87	2.84	2.64	1.30		2.70	2.40
Control Delay	76.0	356.9	848.4		861.3	126.5	859.6	772.6	215.2		807.6	690.8
Queue Delay	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0
Total Delay	76.0	356.9	848.4		861.3	126.5	859.6	772.6	215.2		807.6	690.8
LOS	E	F	F		F	F	F	F	F		F	F

FYP 5:00 pm 4/6/2015 Baseline Synchro 8 Report
Faisal Raza Page 1

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Approach Delay		618.9			824.1			677.1			769.0	
Approach LOS		F			F			F			F	

Intersection Summary	
Area Type: Other	
Cycle Length: 300	
Actuated Cycle Length: 300	
Offset: 0 (0%), Referenced to phase 2:EBTL, Start of Green	
Natural Cycle: 300	
Control Type: Pretimed	
Maximum v/c Ratio: 2.86	
Intersection Signal Delay: 719.3	Intersection LOS: F
Intersection Capacity Utilization 217.4%	ICU Level of Service H
Analysis Period (min) 15	
Description: FYP	
* User Entered Value	
! Phase conflict between lane groups.	

Splits and Phases: 3: Airport Road/Koral Road & Islamabad ExpressWay

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width (ft)	12	12	12	12	12	12	12	12	12	12	12	12
Grade (%)		0%			0%			0%			0%	
Storage Length (ft)	0		400	400		250	50		400	250		250
Storage Lanes	1		2	0		0	0		2	0		0
Taper Length (ft)	25			25			25			25		
Lane Util. Factor	*1.00	*0.86	*0.88	*1.00	*0.86	*1.00	0.91	*1.00	*1.00	*1.00	0.95	*1.00
Ped Bike Factor												
Frt		*0.950	0.850		*0.850	0.850	*0.950	*0.950	0.850		*0.950	0.850
Flt Protected	0.950	*0.850	*0.950		*0.850		*0.850	*0.850	*0.950		*0.850	
Satd. Flow (prot)	1770	5174	2647	0	4630	1583	2738	1504	3006	0	2858	1583
Flt Permitted	0.950	0.850			0.707		0.850	0.850			0.850	
Satd. Flow (perm)	1770	5174	2787	0	3851	1583	2738	1504	3167	0	2858	1583
Right Turn on Red			Yes			No			No			No
Satd. Flow (RTOR)			395									
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		1000			400			1002			1009	
Travel Time (s)		22.7			9.1			22.7			22.7	

Intersection Summary	
Area Type:	Other
Description: FYP	

* User Entered Value

3: Airport Road/Koral Road & Islamabad ExpressWay 4/21/2015

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Volume (vph)	74	2327	2810	559	5826	303	3033	281	1074	210	364	316
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.95	0.88	0.88	0.91	0.96	0.85	0.97	0.88	0.94	0.80	0.90	0.96
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Adj. Flow (vph)	78	2644	3193	614	6069	356	3127	319	1143	262	404	329
Shared Lane Traffic (%)	10%						27%					
Lane Group Flow (vph)	70	2652	3193	0	6683	356	2283	1163	1143	0	666	329

Intersection Summary
Description: FYP

Lane Group	EBL	EBT	EBR	WBT	WBR	NBL	NBT	NBR	SBT	SBR
Lane Configurations										
Volume (vph)	74	2327	2810	5626	303	3033	281	1074	364	316
Turn Type	Split	NA	Perm	NA	Perm	Split	NA	Prot	NA	Perm
Protected Phases	2	2		3		4	4!	4	1	
Permitted Phases			2	4!	3					1
Detector Phase	2	2	2	3	3	4	4	4	1	1
Switch Phase										
Minimum Initial (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Minimum Split (s)	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Total Split (s)	96.0	96.0	96.0	82.0	82.0	92.0	92.0	92.0	30.0	30.0
Total Split (%)	32.0%	32.0%	32.0%	27.3%	27.3%	30.7%	30.7%	30.7%	10.0%	10.0%
Yellow Time (s)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
All-Red Time (s)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Lead/Lag	Lag	Lag	Lag	Lead	Lead	Lag	Lag	Lag	Lead	Lead
Lead-Lag Optimize?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Recall Mode	Max	Max	Max	Max	Max	Max	Max	Max	Max	Max
Act Effct Green (s)	92.0	92.0	92.0	166.0	78.0	88.0	88.0	88.0	26.0	26.0
Actuated g/C Ratio	0.31	0.31	0.31	0.55	0.26	0.29	0.29	0.29	0.09	0.09
v/c Ratio	0.13	1.67	2.83	2.86	0.87	2.84	2.64	1.30	2.70	2.40
Control Delay	76.0	356.9	848.4	861.3	126.5	859.6	772.6	215.2	807.6	690.8
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	76.0	356.9	848.4	861.3	126.5	859.6	772.6	215.2	807.6	690.8
LOS	E	F	F	F	F	F	F	F	F	F
Approach Delay		618.9		824.1			677.1		769.0	
Approach LOS		F		F			F		F	

Intersection Summary	
Cycle Length: 300	
Actuated Cycle Length: 300	
Offset: 0 (0%), Referenced to phase 2:EBTL, Start of Green	
Natural Cycle: 300	
Control Type: Pretimed	
Maximum v/c Ratio: 2.86	
Intersection Signal Delay: 719.3	Intersection LOS: F
Intersection Capacity Utilization 217.4%	ICU Level of Service H
Analysis Period (min) 15	
Description: FYP	

! Phase conflict between lane groups.

Splits and Phases: 3: Airport Road/Koral Road & Islamabad ExpressWay

Lane Group	EBL	EBT	EBR	WBT	WBR	NBL	NBT	NBR	SBT	SBR
Protected Phases	2	2		3		4	4!	4	1	
Permitted Phases			2	4!	3					1
Minimum Initial (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Minimum Split (s)	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Total Split (s)	96.0	96.0	96.0	82.0	82.0	92.0	92.0	92.0	30.0	30.0
Total Split (%)	32.0%	32.0%	32.0%	27.3%	27.3%	30.7%	30.7%	30.7%	10.0%	10.0%
Maximum Green (s)	92.0	92.0	92.0	78.0	78.0	88.0	88.0	88.0	26.0	26.0
Yellow Time (s)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
All-Red Time (s)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Lead/Lag	Lag	Lag	Lag	Lead	Lead	Lag	Lag	Lag	Lead	Lead
Lead-Lag Optimize?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Vehicle Extension (s)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Minimum Gap (s)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Time Before Reduce (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Time To Reduce (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Recall Mode	Max	Max	Max	Max	Max	Max	Max	Max	Max	Max
Walk Time (s)										
Flash Dont Walk (s)										
Pedestrian Calls (#/hr)										
90th %ile Green (s)	92.0	92.0	92.0	78.0	78.0	88.0	88.0	88.0	26.0	26.0
90th %ile Term Code	Coord	Coord	Coord	MaxR	MaxR	MaxR	MaxR	MaxR	MaxR	MaxR
70th %ile Green (s)	92.0	92.0	92.0	78.0	78.0	88.0	88.0	88.0	26.0	26.0
70th %ile Term Code	Coord	Coord	Coord	MaxR	MaxR	MaxR	MaxR	MaxR	MaxR	MaxR
50th %ile Green (s)	92.0	92.0	92.0	78.0	78.0	88.0	88.0	88.0	26.0	26.0
50th %ile Term Code	Coord	Coord	Coord	MaxR	MaxR	MaxR	MaxR	MaxR	MaxR	MaxR
30th %ile Green (s)	92.0	92.0	92.0	78.0	78.0	88.0	88.0	88.0	26.0	26.0
30th %ile Term Code	Coord	Coord	Coord	MaxR	MaxR	MaxR	MaxR	MaxR	MaxR	MaxR
10th %ile Green (s)	92.0	92.0	92.0	78.0	78.0	88.0	88.0	88.0	26.0	26.0
10th %ile Term Code	Coord	Coord	Coord	MaxR	MaxR	MaxR	MaxR	MaxR	MaxR	MaxR

Intersection Summary

Cycle Length: 300

Actuated Cycle Length: 300

Offset: 0 (0%), Referenced to phase 2:EBTL, Start of Green

Control Type: Pretimed

Description: FYP

! Phase conflict between lane groups.

Lane Group	EBL	EBT	EBR	WBT	WBR	NBL	NBT	NBR	SBT	SBR
Lane Group Flow (vph)	70	2652	3193	6683	356	2283	1163	1143	666	329
v/c Ratio	0.13	1.67	2.83	2.86	0.87	2.84	2.64	1.30	2.70	2.40
Control Delay	76.0	356.9	848.4	861.3	126.5	859.6	772.6	215.2	807.6	690.8
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	76.0	356.9	848.4	861.3	126.5	859.6	772.6	215.2	807.6	690.8
Queue Length 50th (ft)	102	~2221	~5849	~6593	689	~4250	~3875	~1443	~1173	~1071
Queue Length 95th (ft)	158	#2150	#5614	#6295	787	#4289	#4003	#1564	#1316	#1317
Internal Link Dist (ft)		920		320			922		929	
Turn Bay Length (ft)			400		250	50		400		250
Base Capacity (vph)	542	1586	1128	2333	411	803	441	882	247	137
Starvation Cap Reductn	0	0	0	0	0	0	0	0	0	0
Spillback Cap Reductn	0	0	0	0	0	0	0	0	0	0
Storage Cap Reductn	0	0	0	0	0	0	0	0	0	0
Reduced v/c Ratio	0.13	1.67	2.83	2.86	0.87	2.84	2.64	1.30	2.70	2.40

Intersection Summary

Description: FYP

~ Volume exceeds capacity, queue is theoretically infinite.
Queue shown is maximum after two cycles.

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Enter Blocked Intersection	No	No	No	No	No	No	No	No	No	No	No	No
Lane Alignment	Left	Left	Right	Left	Left	Right	Left	Left	Right	Left	Left	Right
Median Width(ft)		12			12			30			0	
Link Offset(ft)		0			0			0			0	
Crosswalk Width(ft)		16			16			16			16	
Two way Left Turn Lane												
Headway Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Turning Speed (mph)	15		9	15		9	15		9	15		9

Intersection Summary
Description: FYP

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	74	2327	2810	559	5826	303	3033	281	1074	210	364	316
Pedestrians												
Ped Button												
Pedestrian Timing (s)												
Free Right			No			No			No			No
Ideal Flow	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lost Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Minimum Green (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Refr Cycle Length (s)	120	120	120	120	120	120	120	120	120	120	120	120
Volume Combined (vph)	0	2401	2810	0	6385	303	0	3314	1074	0	574	316
Lane Utilization Factor	1.00	0.91	0.89	1.00	0.91	1.00	0.97	1.00	0.89	1.00	0.95	1.00
Turning Factor (vph)	0.95	1.00	0.85	0.95	1.00	0.85	0.95	0.95	0.85	0.95	0.98	0.85
Saturated Flow (vph)	0	8613	2859	0	6871	1615	0	5439	2859	0	3551	1615
Ped Intf Time (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pedestrian Frequency (%)		0.00			0.00			0.00			0.00	
Protected Option Allowed		No			No			No			No	
Reference Time (s)			118.0			22.5			45.1			23.5
Adj Reference Time (s)			122.0			26.5			49.1			27.5
Permitted Option												
Adj Saturation A (vph)	0	542		0	115		0	384		0	118	
Reference Time A (s)	0.0	83.7		0.0	585.8		0.0	1034.3		0.0	212.9	
Adj Saturation B (vph	NA	NA		NA	NA		NA	NA		NA	NA	
Reference Time B (s)	NA	NA		NA	NA		NA	NA		NA	NA	
Reference Time (s)		83.7			585.8			1034.3			212.9	
Adj Reference Time (s)		87.7			589.8			1038.3			216.9	
Split Option												
Ref Time Combined (s)	0.0	33.5		0.0	111.5		0.0	73.1		0.0	19.4	
Ref Time Seperate (s)	2.5	40.5		37.2	101.3		69.2	17.7		14.0	12.1	
Reference Time (s)	40.5	40.5		111.5	111.5		73.1	73.1		19.4	19.4	
Adj Reference Time (s)	44.5	44.5		115.5	115.5		77.1	77.1		23.4	23.4	

Summary	EB WB	NB SB	Combined
Protected Option (s)	NA	NA	
Permitted Option (s)	589.8	1038.3	
Split Option (s)	160.0	100.5	
Minimum (s)	160.0	100.5	260.5

Right Turns	EBR	WBR	NBR	SBR
Adj Reference Time (s)	122.0	26.5	49.1	27.5
Cross Thru Ref Time (s)	23.4	77.1	44.5	115.5
Oncoming Left Ref Time (s)	115.5	44.5	23.4	77.1
Combined (s)	260.9	148.1	116.9	220.1

Intersection Summary

Intersection Capacity Utilization 217.4% ICU Level of Service H

Reference Times and Phasing Options do not represent an optimized timing plan.

APPENDIX D- SYNCHRO REPORTS FOR IMPROVED CONDITIONS IN 2015

Performance Evaluation of Koral

3: Airport Road/Koral Road & Islamabad ExpressWay 25/05/2015

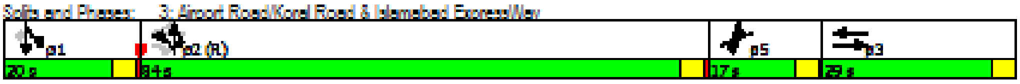
Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		6			6							
Volume (vph)	74	2327	2810	559	5826	303	3033	281	1074	210	364	316
Lane Util. Factor	*1.00	*0.86	*0.88	*1.00	*0.86	*1.00	0.97	*1.00	*1.00	*1.00	0.91	*1.00
Ped Bike Factor												
Frt		*0.950	0.850		*0.850	0.850	*0.950	*0.950	0.850		*0.950	0.850
Flt Protected	0.950	*0.850	*0.950	0.950	*0.850		*0.850	*0.850	*0.950	0.950	*0.850	
Satd. Flow (prot)	3539	7762	2647	3539	6945	3167	2918	4512	3008	1770	4106	1583
Flt Permitted	0.950			0.950			0.850			0.950		
Satd. Flow (perm)	3539	9131	2787	3539	8170	3167	2918	5309	3167	1770	4831	1583
Satd. Flow (RTOR)			892									
Adj. Flow (vph)	80	2529	3054	608	6333	329	3297	305	1167	228	396	343
Lane Group Flow (vph)	80	2529	3054	608	6333	329	3297	305	1167	228	396	343
Enter Blocked Intersection	No	No	No	No	No	No	No	No	No	No	No	No
Lane Alignment	Left	Left	Right	Left	Left	Right	Left	Left	Right	Left	Left	Right
Median Width(ft)		24			24			30			24	
Link Offset(ft)		0			0			0			0	
Crosswalk Width(ft)		16			16			16			16	
Two way Left Turn Lane												
Headway Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Turning Speed (mph)	15		9	15		9	15		9	15		9
Turn Type	Prot	NA	custom	Prot	NA	custom	Split	NA	Prot	Split	NA	Perm
Protected Phases	5	3		5	3		2	2!	2	1	1	
Permitted Phases			2		2!	2						1
Total Split (s)	17.0	29.0	84.0	17.0	29.0	84.0	84.0	84.0	84.0	20.0	20.0	20.0
Total Lost Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Act Effct Green (s)	13.0	25.0	80.0	13.0	105.0	80.0	80.0	80.0	80.0	16.0	16.0	16.0
Actuated g/C Ratio	0.09	0.17	0.53	0.09	0.70	0.53	0.53	0.53	0.53	0.11	0.11	0.11
v/c Ratio	0.26	1.96	1.61	1.99	1.15	0.19	2.12	0.13	0.73	1.21	0.91	2.04
Control Delay	66.4	464.3	296.3	488.0	90.4	18.6	528.4	17.7	30.0	188.3	90.8	519.9
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	66.4	464.3	296.3	488.0	90.4	18.6	528.4	17.7	30.0	188.3	90.8	519.9
LOS	E	F	F	F	F	B	F	B	C	F	F	F
Approach Delay		368.1			120.4			373.8			266.0	
Approach LOS		F			F			F			F	
Stops (vph)	68	1472	1498	352	5532	153	1842	135	800	168	338	198
Fuel Used(gal)	2	246	200	62	183	4	360	4	19	11	11	37
CO Emissions (g/hr)	137	17212	13960	4323	12805	304	25197	278	1362	742	800	2587
NOx Emissions (g/hr)	27	3349	2716	841	2491	59	4902	54	265	144	156	503
VOC Emissions (g/hr)	32	3989	3235	1002	2968	71	5840	65	316	172	185	600
Dilemma Vehicles (#)	0	0	0	0	0	0	0	0	0	0	0	0
Queue Length 50th (ft)	37	~739	~2194	~461	~1163	81	~2634	48	423	~271	142	~525
Queue Length 95th (ft)	65	#783	#2306	#581	#1142	110	#2724	65	507	#448	#206	#727
Internal Link Dist (ft)		920			320			935			922	
Turn Bay Length (ft)	400		400	400		400	50		400	250		250
Base Capacity (vph)	306	1293	1902	306	5514	1689	1556	2406	1604	188	437	168
Starvation Cap Reductn	0	0	0	0	0	0	0	0	0	0	0	0
Spillback Cap Reductn	0	0	0	0	0	0	0	0	0	0	0	0
Storage Cap Reductn	0	0	0	0	0	0	0	0	0	0	0	0
Reduced v/c Ratio	0.26	1.96	1.61	1.99	1.15	0.19	2.12	0.13	0.73	1.21	0.91	2.04

FYP 5:00 pm 06/04/2015 Baseline Synchro 8 Report

Faisal Raza Page 1

Intersection Summary	
Cycle Length: 150	
Actuated Cycle Length: 150	
Offset: 0 (0%), Referenced to phase 2:NBWB, Start of Green	
Control Type: Pretimed	
Maximum v/c Ratio: 2.12	
Intersection Signal Delay: 267.8	Intersection LOS: F
Intersection Capacity Utilization 172.4%	ICU Level of Service H
Analysis Period (min) 15	
Description: FYP	
* User Entered Value	
~ Volume exceeds capacity, queue is theoretically infinite.	
Queue shown is maximum after two cycles.	
# 95th percentile volume exceeds capacity, queue may be longer.	
Queue shown is maximum after two cycles.	
! Phase conflict between lane groups.	

Splits and Phases: 3: Airport Road/Koral Road & Islamabad ExpressWay



APPENDIX E- SYNCHRO REPORTS FOR IMPROVED CONDITIONS IN 2015

Performance Evaluation of Koral

3: Airport Road/Koral Road & Islamabad ExpressWay 25/05/2015

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		6			6							
Volume (vph)	74	2327	2810	559	5826	303	3033	281	1074	210	364	316
Lane Util. Factor	*1.00	*0.86	*0.88	*1.00	*0.86	*1.00	0.97	*1.00	*1.00	*1.00	0.91	*1.00
Ped Bike Factor												
Frt		*0.950	0.850		*0.850	0.850	*0.950	*0.950	0.850		*0.950	0.850
Flt Protected	0.950	*0.850	*0.950	0.950	*0.850		*0.850	*0.850	*0.950	0.950	*0.850	
Satd. Flow (prot)	3539	7762	2647	3539	6945	3167	2918	4512	3008	1770	4106	1583
Flt Permitted	0.950			0.950			0.850			0.950		
Satd. Flow (perm)	3539	9131	2787	3539	8170	3167	2918	5309	3167	1770	4831	1583
Satd. Flow (RTOR)			869									
Adj. Flow (vph)	161	5059	6109	1215	12665	659	6593	611	2335	457	791	687
Lane Group Flow (vph)	161	5059	6109	1215	12665	659	6593	611	2335	457	791	687
Enter Blocked Intersection	No	No	No	No	No	No	No	No	No	No	No	No
Lane Alignment	Left	Left	Right	Left	Left	Right	Left	Left	Right	Left	Left	Right
Median Width(ft)		24			24			30			24	
Link Offset(ft)		0			0			0			0	
Crosswalk Width(ft)		16			16			16			16	
Two way Left Turn Lane												
Headway Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Turning Speed (mph)	15		9	15		9	15		9	15		9
Turn Type	Prot	NA	custom	Prot	NA	custom	Split	NA	Prot	Split	NA	Perm
Protected Phases	5	3		5	3		2	2!	2	1	1	
Permitted Phases			2		2!	2						1
Total Split (s)	32.0	56.0	93.0	32.0	56.0	93.0	93.0	93.0	93.0	39.0	39.0	39.0
Total Lost Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Act Effct Green (s)	28.0	52.0	89.0	28.0	141.0	89.0	89.0	89.0	89.0	35.0	35.0	35.0
Actuated g/C Ratio	0.13	0.24	0.40	0.13	0.64	0.40	0.40	0.40	0.40	0.16	0.16	0.16
v/c Ratio	0.36	2.76	3.72	2.70	2.56	0.51	5.59	0.33	1.92	1.63	1.21	2.74
Control Delay	90.3	817.7	1237.7	798.5	721.4	51.0	2077.0	45.8	449.9	346.8	180.5	819.1
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	90.3	817.7	1237.7	798.5	721.4	51.0	2077.0	45.8	449.9	346.8	180.5	819.1
LOS	F	F	F	F	F	D	F	D	F	F	F	F
Approach Delay		1033.9			697.5			1548.6			446.5	
Approach LOS		F			F			F			F	
Stops (vph)	134	2425	2412	586	6276	448	3647	379	1281	279	608	332
Fuel Used(gal)	5	824	1473	194	1837	13	2633	12	221	34	36	112
CO Emissions (g/hr)	323	57631	102960	13539	128395	943	184060	823	15435	2410	2502	7840
NOx Emissions (g/hr)	63	11213	20036	2634	24981	184	35811	160	3003	469	487	1525
VOC Emissions (g/hr)	75	13357	23867	3138	29757	219	42658	191	3577	558	580	1817
Dilemma Vehicles (#)	0	0	0	0	0	0	0	0	0	0	0	0
Queue Length 50th (ft)	109	~2408	~8633	~1485	~5926	361	~9284	204	~2590	~949	~510	~1684
Queue Length 95th (ft)	152	#2362	#8387	#1615	#5582	424	#9017	239	#2674	#1195	#608	#1948
Internal Link Dist (ft)		920			320			935			922	
Turn Bay Length (ft)	400		400	400		400	50		400	250		250
Base Capacity (vph)	450	1834	1644	450	4946	1281	1180	1825	1216	281	653	251
Starvation Cap Reductn	0	0	0	0	0	0	0	0	0	0	0	0
Spillback Cap Reductn	0	0	0	0	0	0	0	0	0	0	0	0
Storage Cap Reductn	0	0	0	0	0	0	0	0	0	0	0	0
Reduced v/c Ratio	0.36	2.76	3.72	2.70	2.56	0.51	5.59	0.33	1.92	1.63	1.21	2.74

FYP 5:00 pm 06/04/2015 Baseline Synchro 8 Report
Faisal Raza Page 1

Intersection Summary	
Cycle Length: 220	
Actuated Cycle Length: 220	
Offset: 0 (0%), Referenced to phase 2:NBWB, Start of Green	
Control Type: Pretimed	
Maximum v/c Ratio: 5.59	
Intersection Signal Delay: 1003.9	Intersection LOS: F
Intersection Capacity Utilization 334.8%	ICU Level of Service H
Analysis Period (min) 15	
Description: FYP	
* User Entered Value	
~ Volume exceeds capacity, queue is theoretically infinite.	
Queue shown is maximum after two cycles.	
# 95th percentile volume exceeds capacity, queue may be longer.	
Queue shown is maximum after two cycles.	
! Phase conflict between lane groups.	

Splits and Phases: 3: Airport Road/Koral Road & Islamabad ExpressWay