EIN SARA HAPPY BUNNY INTERSECTION DESIGN

By

Ishaq Rajabi

Sara Al-Zeer

Supervisor: Musab AA Shahin

Submitted to the College of Engineering in partial

fulfillment of the requirements for the degree of

Bachelor degree in Surveying and Geomatics Engineering

Palestine Polytechnic University

May 2015

EIN SARA HAPPY BUNNY INTERSECTION DESIGN

Supervisor: Musab AA Shahin

Submitted by: Ishaq Rajabi

Sara Al-Zeer

Palestine Polytechnic University

Abstract

This project aims to study the traffic and Geometry of "Ein Sara Happy Bunny" junction by making two or three alternatives to solve the traffic congestion.

Traffic count, collision histories, signal timing and surveying shall be conducted. The collected field data and observations will be organized and analyzed by Highway capacity Manual 2010 producer. Different modeling tools will be used to analyze the existing and proposed condition. The analysis leads to the development of possible design alternatives that were evaluated in order to determine which would be recommended. Set of recommendations would be sent to Hebron Municipality to be considered as future solution for this intersection. The Model will reveal safety and effectiveness results.

تصميم تقاطع "الهابي باني" في شارع عين ساره

المشرف :م.مصعب شاهين

مقدم من : اسحق الرجبي

ساره الزير

جامعة بوليتكنيك فلسطين

ملخص

يهدف المشروع لدراسة تقاطع" الهابي باني" في شارع عين ساره, وذلك من خلال عمل عدة بدائل لحل الازمه المرورية .سوف يتم الأخذ بعين الاعتبار عدد السيارات,التصادمات التي حدثت خلال السنوات السابقة والأعمال المساحية للتقاطع .بعد ذلك سوف يتم تحليل وتنظيم المعلومات والقراءات التي تم جمعها من خلال HCM 2010 ,والعديد من أدوات التصميم ستستخدم لتطوير البدائل المحتملة لتحديد ما سيتم التوصية به . سيتم ارسال مجموعه من التوصيات لمجلس بلدية الخليل لاخذها بعين الاعتبار لتطوير التقاطع في المستقبل. التصميم سيوفر الامن والفعاليه للتقاطع .

Table of Contents

Table of Figures

Chapter One: Introduction

Chapter Two: Background

Chapter Three: Methodology

Chapter Four: Design alternatives

Appendices

Table of Tables

Chapter one: Introduction

Chapter two: Background

Chapter Three: Methodology

Chapter Four: Design Alternatives

Appendices

CHAPTER ONE

Introduction

Chapter One

1.1 background

Intersections are a critical component of the roadway system frequently act as a choke points on the traffic system. In addition, intersection crashes account for approximately 39.7 % of all crashes (Federal Highway Administration 2007). As critical component of the traffic system, intersection design is balancing act of various elements and constrains to produce a solution that will address mobility, safety, environment and financial aspects of the project. From this point of view the Traffic Engineering students o to conduct a study on the possible redesign of the intersection of happy bunny "Ein Sara Street" which is the vein of Hebron city center.

1.2 Location Description

"The intersection is located in Ein Sara Street in Hebron city (Figure 1.1). **Hebron ((Khalil Al-Rahman)** is one of the oldest continuously inhabited towns in the world, its Arabic name, *Khalil al-Rahman*. Ancient Hebron was situated on Jebel Ar-Rumeideh (the Rumeideh hill), located southwest of the current historic town. It lies 930 meters above sea level. Archaeological investigations show several layers of habitation, dating from the Chalcolithic period down to the Umayyad period The city has always been known as the burial place of the prophets Abraham/Ibrahim, Ishaq, Jacob and their wives. During the Roman period, Herod the Great (73-4 BC) built a massive wall to enclose the cave of the prophets' tombs. After the conquest of Hebron by the Crusaders (1099), this enclosure was turned into a church, and subsequently, after Salah Al-din's retaking of the city in 1187, into a mosque. Inside it, a walnut-wood carved *minbur* (pulpit) stands near the prayer niche. It was brought by Salah Al-din from Egypt and is believed to be among the oldest wooden Islamic pulpits.

Hebron is a busy hub of Palestinian trade, responsible for roughly a third of the area's gross domestic product, largely due to the sale of marble from quarries. It is locally well known for its grapes, figs, limestone, pottery workshops and glassblowing factories. The old city of Hebron is characterized by narrow, winding streets, flat-roofed stone houses, and old bazaars. The city is home to Hebron University and the Palestine Polytechnic University and notably has no cinemas or places of entertainment. Hebron is detached to cities of ad-Dhahiriya, Dura, Yatta and Halhoul, the surrounding villages with no borders. Hebron is also the largest Palestinian governorate with its population of 600,364 (2010).

Figure 1. 1: Aerial Photo of the Happy Bunny intersection "Ein Sara Street"

1.3 Project objective

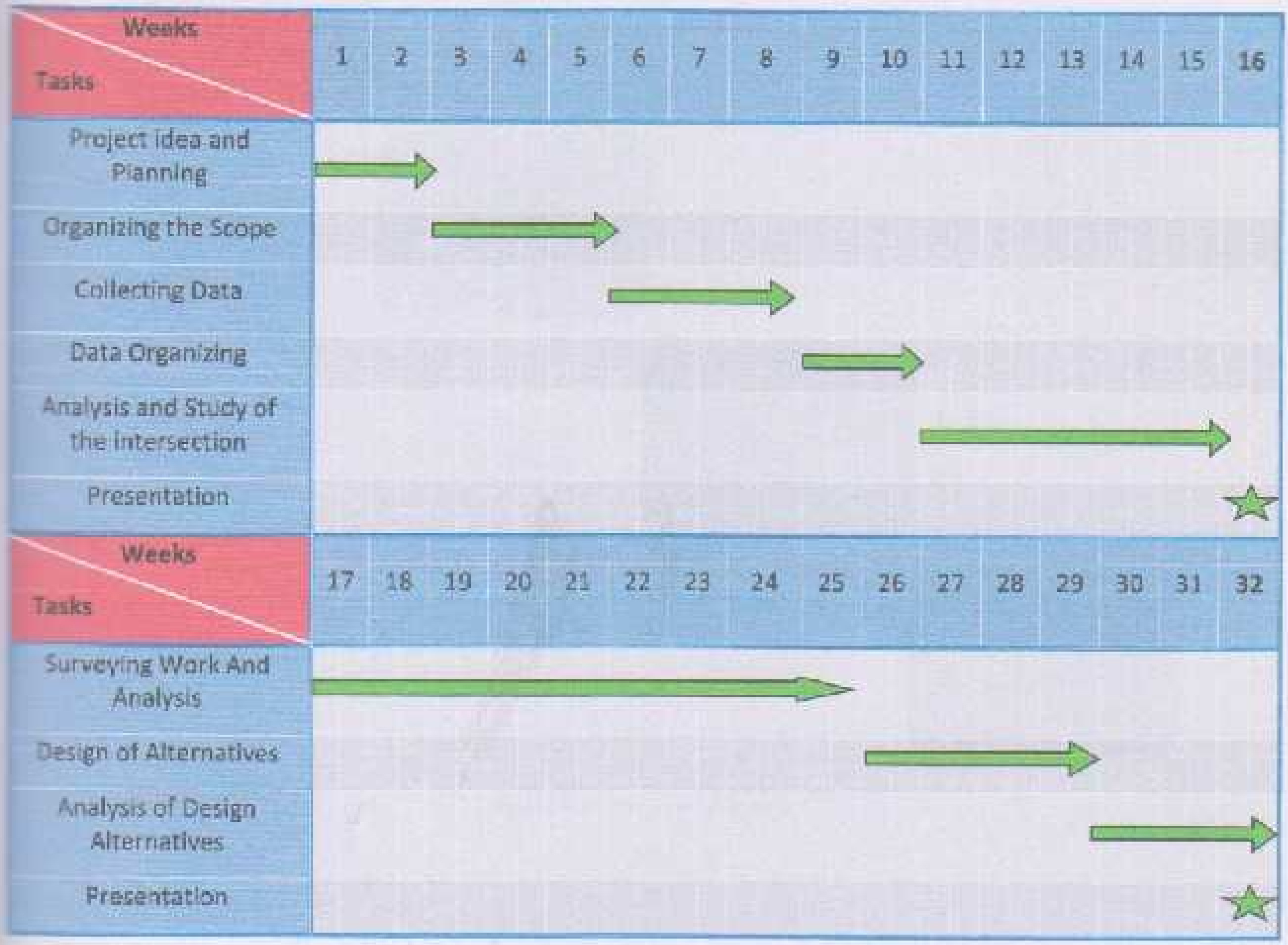
The traffic flow patterns in the intersection and the bad geometry of the intersection are part of why a redesign of this particular intersection needs to be explored. The purpose of this project is the analysis, and re-design of the intersection. We would like to improve the flow of traffic through this intersection. The solutions could be as simple as changing the traffic signal timing, or maybe as complex as re-designing the geometry of the entire intersection. One of the current problems with the intersection it's geometry and the driver behavior which decrease the level of service of the intersection. The objective of this study is to analyze and re-design the intersection to increase its safety and efficiency.

- Traffic study (level of service) for existing conditions
- Geometric Enhancement

1.4 Project Timeline

In this project we planned for our work as illustrated in the following table:

Table 1. 1: Project Timeline



1.5 Project Scope of work

Our team would like to find solutions to all of the flow and safety problems experienced at this intersection. If the city is able to control these issues, the traffic would flow through this intersection with relative ease. To accomplish the project objective, traffic data must be collected, the data must be analyzed, a new design formulated, and a cost-benefit analysis for each of the recommendations will be performed. This analysis will show which of the recommendations are the most realistic and the most cost-effective with the materials and tools that are at the city's disposal.

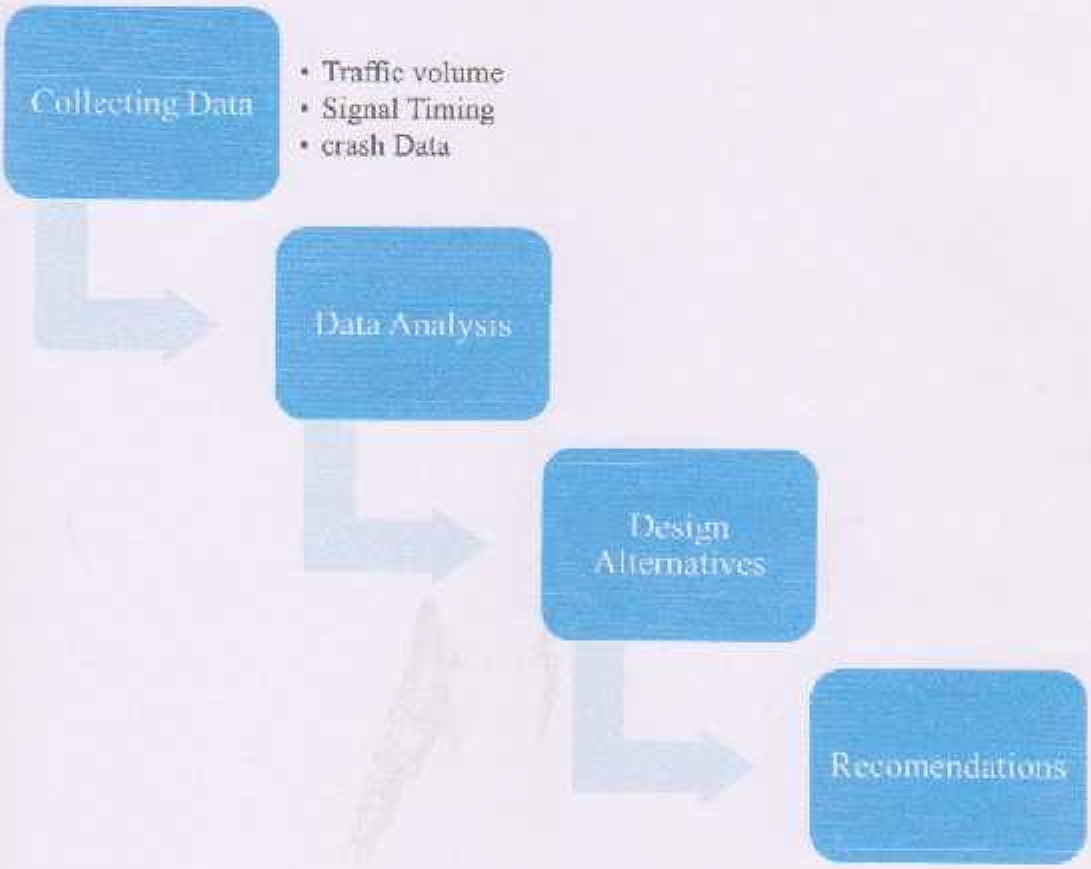


Figure 1. 2: Design methodology

The goal of the following chapters will be to understand all of the intersections deficiencies that are greater issues now than in previous years.

- Chapter two will be discussing the existing conditions of the intersections in question as well as the sources that have been used for this project.
- Chapter three will present the data which gathered in visits to the intersection.
- Chapter four shows the basics of analysis
- Chapter five a presentation of the design alternatives recommended alternatives.

CHAPTER TWO

Background

Chapter 2: Background

In order to gain perspective into the intersection being studied, it is important to examine background texts and refer to materials that outline industry standards relating to intersection design. Putting in mind the aim of the project which is to improve the overall efficiency and safety, by proposing a series of Alternatives. This chapter provides a context by describing the existing conditions of the intersection and detailing the necessary guidebooks that will be used to assure the proposed design of this intersection meets industry standards and the aim of the project. Overall, which is divided into:

- Existing Conditions
- Intersection Design Procedure
- AASHTO & HCM2010
- Microsimulation

And we are going to give a general Idea about intersections in traffic engineering

2.1 Existing Conditions

The intersection is a four way signalized at Ein Sara, which is the major street for signal purposes. The northbound and southbound approaches has four lanes; two of them are through, one exclusive for the left turn and another for the right turn. The eastbound approach has one lane for through and left turns and an exclusive lane for right turn. The Following figures illustrates the existing conditions.

Figure 2. 1: Existing Conditions South approach

Figure 2. 2: Existing Condition North approach

Figure 2. 3: Existing condition West approach

Figure 2. 4: Existing condition East approach

2.2 Intersection Design Procedure

In order to analysis to find out the ways, to re-design them, certain procedures are followed and carried out. The amount of traffic going through an intersection is the most important aspect of this and is determined through collecting various types of data. These data are then analyzed by traffic procedure to determine what can be done to ensure clean operation.

2.2.1 Traffic volumes counts

Traffic volume studies are conducted to determine the number, movements, and classifications of roadway vehicles at a given location. These data can help identify critical flow time periods, determine the influence of large vehicles or pedestrians on vehicular traffic flow, or document traffic volume trends. The length of the sampling period depends on the type of count being taken and the intended use of the data recorded. For example, an intersection count may be conducted during the peak flow period. If so, manual count with 15-minute intervals could be used to obtain the traffic volume data

Two methods are available for conducting traffic volume counts: (1) manual and (2) automatic. Manual counts are typically used to gather data for determination of vehicle classification, turning movements, direction of travel, pedestrian movements, or vehicle occupancy. Automatic counts are typically used to gather data for determination of vehicle hourly patterns, daily or seasonal variations and growth trends, or annual traffic estimates. The selection of study method should be determined using the count period. The count period should be representative of the time of day, day of month, and month of year for the study area. For example, counts at a summer resort would not be taken in January. The count period should avoid special event or compromising weather conditions (Sharma 1994). Count periods may range from 5 minutes to 1 year. Typical count periods are 15 minutes or 2 hours for peak periods, 4 hours for morning and afternoon peaks, 6 hours for morning, midday, and afternoon peaks, and 12 hours for daytime periods (Robertson 1994). For example, if you were conducting a 2-hour peak period count, eight 15-minute counts would be required.

Unfortunately the technology in counting weren't provided by the city municipality in Hebron city, so we resorted to manual counting by setting four persons on the intersection, each one count the cars and heavy vehicles from one of the intersection approach. Most applications of manual counts require small samples of data at any given location. Manual counts are sometimes used when the effort and expense of automated equipment are not justified. Manual counts are necessary when automatic equipment is not available.

Here we illustrate and talk a little about some technologies which are used in traffic counting by taking in mind that the fragility of traffic engineering in general in this city and west bank.

Automatic Traffic Recorder (ATR) Counts are used in many countries and institutes to find the amount of traffic going through the intersections over the course of an average week. These are done with electronic ATRs. These find information about the roadways such as volume, speed and number of trucks. The results of these are used towards analyzing different pieces of information including Average Daily Traffic, Average Annual Daily Traffic, accident rates, and peak hours. In a similar fashion to ATR counts, Traffic Management Center (TMCs) are used to determine the trends of traffic flow in intersections. These are done according to procedure and are during times of the day when traffic is at its highest, known as peak hours. With the use of ATR and TMC counts, numbers are made available for the purpose of designs.

2.2.2 Peak Hour Factor

The relationship between the hourly volume and the maximum rate of flow within the hour is defined by the peak hour factor, as follows:

$$PHF = \frac{Hourly\ volume}{max.rate\ of\ flow} \qquad (2.1)$$

For standard 15- minute analysis period, this becomes:

$$PHF = \frac{V}{4 * Vm15} \qquad (2.2)$$

Where: V = hourly volume, vehs

V_{m15} = maximum 15-Minute volume within the hour, vhs

PHF = peak hour factor

The maximum possible value for the PHF is 1.00, which occurs when the volume in each interval is constant. For 15-minute periods, each would have a volume of exactly one quarter of the full hour volume. This indicates a condition in which there is virtually no variation of flow within the hour. The minimum value occurs when the entire hourly volume occurs in a single 15- minute interval. In this case, the PHF becomes 0.25, and represents the most extreme case of volume variation within the hour. In practical terms, the PHF generally varies between a low 0.7 for rural and sparsely developed areas to 0.98 in dense urban areas

The peak- hour factor is descriptive of trip generation patterns and may apply to an area or portion of a street and highway system. When the value is known, it can be used to estimate a maximum flow rate within an hour based on full hour- volume:

$$v = \frac{V}{PHF} \qquad (2.3)$$

Where: v = maximum rate of flow within the hour veh/h

V = hourly volume, vehs

PHF = peak hour factor

2.2.3 Signal Timing

The signal timing of an intersection is of great importance to an intersection study. This is the amount of time the intersection controller sets aside for each approach at an intersection. Signal timing is divided into phases. A phase is the amount of time given for a certain approach to be given clearance to proceed through the intersection, via a green (and eventually yellow) light. The phasing and timing of an intersection can be determined by visiting the intersection firsthand and measuring time intervals. In the situation of the current intersection.

2.3 Analysis

Once the data was collected, the following analyses were conducted:

- Compiled all counts and examined for trends and in consistencies,
- Review the connection between accident and the intersection,
- Perform signal timing analysis and
- Perform a level of service analysis.

The analysis was to address the issue of signal timing and phasing. The current timing was analyzed for its level of service. This involved the use of a software Syncro 9 and vissim. For this analysis, counting data was entered into the program along with signal timing data and intersection geometry procured from field observations. For the purpose of analyzing the worst case scenario of the intersection, the maximum timings for each phase were used for the LOS analysis to simulate the worst case scenario. This entails entering peak hour values into software to determine what the level of service of the intersection is. This is a letter grade, ranging from "A" (optimum) to" F" (failure to operate).

The findings that were generated through various data collection activities and observations were then used to analyze the conditions of the intersection, and eventually lead to the evaluation of changes recommended at the intersection. The analysis consists of:

- Level of Service Analysis,
- Critical Analysis and
- Visual Analysis.

2.3.1 Level of Service Analysis

The initial conditions of the intersection were analyzed using Synchro 9, a program that performs a level of service analysis of signalized intersections. The initial information entered into the program was done with the volume collected through field counting a discussed in the previous chapter. The maximum interval length for each phase was used in the analysis, because it was believed to be the most problematic situation. The afternoon peak hours weren't that different from the morning peak hour, therefore the level of service (LOS) conclusions were based off of the results for the morning and afternoon peak hour. A level of service analysis is based off of the delay the average vehicle must experience in order to go through the intersection. The volumes during the peak hour, the peak hour factors, the geometry of the intersection, and the signal timings are all inputted into Synchro 9, and the average delay is calculated. The amount of delay is then defined by a letter "grade." If the delay is between zero and ten seconds, the grade is an "A," between ten and twenty, a "B," between twenty and thirty, a "C," and so forth.

2.3.2 Conceptual Framework for the HCM 2000 Methodology

There are five fundamental concepts used in the HCM 2000 signalized intersection analysis methodology that should be understood before considering any of the details of the model. These are:

- The critical lane group concept

- The v/s ratio as a measure of demand
- Capacity and saturation flow rate concepts
- Level-of-service criteria and concepts
- Effective green time and lost-time concepts

2.3.3 Saturation flow rates

The key, and most complex, part of the HCM model is a methodology for estimating the saturation flow rate of any lane group based on known prevailing traffic parameters. The algorithm takes the form:

$$s_0 = s_i N \Pi f_i \qquad (2.4)$$

Where: S_i= saturation flow rate of lane group i under prevailing conditions, veh/hg

S_0 = saturation flow rate per lane under base conditions, pc/hg/ln

N = number of lanes in the lane group

f_i = multiplicative adjustment factor for each prevailing condition i

The HCM now provides 11 adjustment factors covering a wide variety of potential prevailing conditions. Each adjustment factor involves a separate model, some of which are quite complex. (Refer to Traffic Engineering text book P.Roess for more information)

2.3.4 Capacity of a Lane Group

The saturation flow rate is an estimate of the capacity of a lane group if the signal were green 100% of the time. In fact, the signal is only effectively green for a portion of the time. Thus:

$$C_i = S_i \, {g_i}/{C} \qquad (2.5)$$

Where: C_i = capacity of lane group i, veh/h

S_i = saturation flow rate of lane group i, veh/hg

g_i = effective green time for lane group i, s

C = cycle length, s

2.3.5 The v/c Ratio

In signal analysis, the VIC ratio is often referred to as the "degree of saturation" and given the symbol "X." This is convenient, as the term "vIc" appears in many equations that can be more simply expressed using a single variable, X.

The v/c ratio, or degree of saturation, is a principal output measure from the analysis of a signalized intersection. It is a measure of the sufficiency of available capacity to handle existing or projected demands. Obviously, cases in which VIC > 1.00 indicate a shortage of capacity to handle the demand. Care must be taken, however, in analyzing such cases, depending on how the vlc value was determined.

$$X_i = \frac{v_i}{C_i} = \frac{(v/s)_i}{(g/C)_i} \qquad (2.6)$$

Where: Xi = degree of saturation (vlc ratio) for lane group i

vi = demand flow rate for lane group i, veh/h

C_i = capacity for lane group i, veh/h

$(v/s)_i$ = flow ratio for lane group i

$(g/C)_i$ = green ratio for lane group i

$$Xc = \frac{\sum_i v_{ci}}{\sum_i \left(s_{ci} \cdot \frac{g_{ci}}{C}\right)} = \frac{\sum_i (v/s)_{ci}}{\sum_i \left(g_{ci}/C\right)} \quad (2.7)$$

Where: X_c = critical v/c ratio for the intersection

V_{ci} = demand flow rate for critical lane group i, veh/h

S_{ci} = saturation flow rate for critical lane group i, veh/hg g

g_{ci} = effective green time for critical lane group i, s

C = cycle length, s

The critical v/c ratio, X, is an important indicator of capacity sufficiency in analysis. If X_c is ≤ 1.00 then the proposed physical design, cycle length, and phase plan are sufficient to handle all critical demands. This does not mean that all lane groups will operate at Xi ≤1.00. It does, however, indicate that all critical lane groups can achieve Xi ≤1.00 by reallocating the green time within the existing cycle and phase plan. When X_c > 1.00, then sufficient capacity may be provided only by one or more of the following actions:

- Increasing the cycle length
- Devising a more efficient phase plan
- Adding a lane or lanes to one or more critical lane groups

2.3.6 Level-of-Service Concepts and Criteria

Level of service is defined in the HCM in terms of total control delay per vehicle in a lane group. "Total control delay" is basically time in queue delay, plus acceleration-deceleration delay. Level- of-service criteria are shown in Table

Table 2. 1: Level of service criteria

Level of Service	Control Delay (s/veh)
A	≤10
B	>10-20
C	>20-35
D	>35-55
E	>55-80
F	>80

Delay is not a simple measure, however, and varies (in order of importance) with the following measures:

- Quality of progression
- Cycle length
- Green time
- v/c ratio

2.3.7 Effective Green Times and Lost Times

In terms of capacity analysis, any given movement has effective green time, gi, and effective red time, rj. Table illustrates how these values are related to actual green, yellow, and red times in the HCM

$$g_i = G_i + Y_i - l_i$$

$$g_i = G_i - l_i + e \quad (2.8)$$

$$r_i = C - g_i$$

Table 2. 2: Relations to actual green, yellow, and red times in the HCM

G		y	ar	R
L_1		e	L_2	R
t_L	g			R
r	R			R

Where: g_i = effective green time for Phase i, s

G_i = actual green time for Phase i, s

$Y_i = y_i + ar_i$ sum of yellow and all-red time for Phase i, s

t_{Li} = total lost time for Phase i, s

L_i= start-up lost time, s

e =extension of effective green into yellow and all-red.s

2.3.7 Analysis Time Periods

The basic time period for analysis recommended by the HCM remains a peak 15-minute period within the analysis hour, which is most often (but need not be) one of the peak hours of the day. The HCM 2000, however, provides for some flexibility in this regard, recognizing that delay is particularly sensitive to the analysis period, especially when oversaturation exists. There are three basic time options for analysis:

1. The peak 15 minutes within the analysis hour
2. The full 60-min analysis hour
3. Sequential 15-min periods for an analysis period of one hour or greater

2.3.8 The basic structure of HCM model

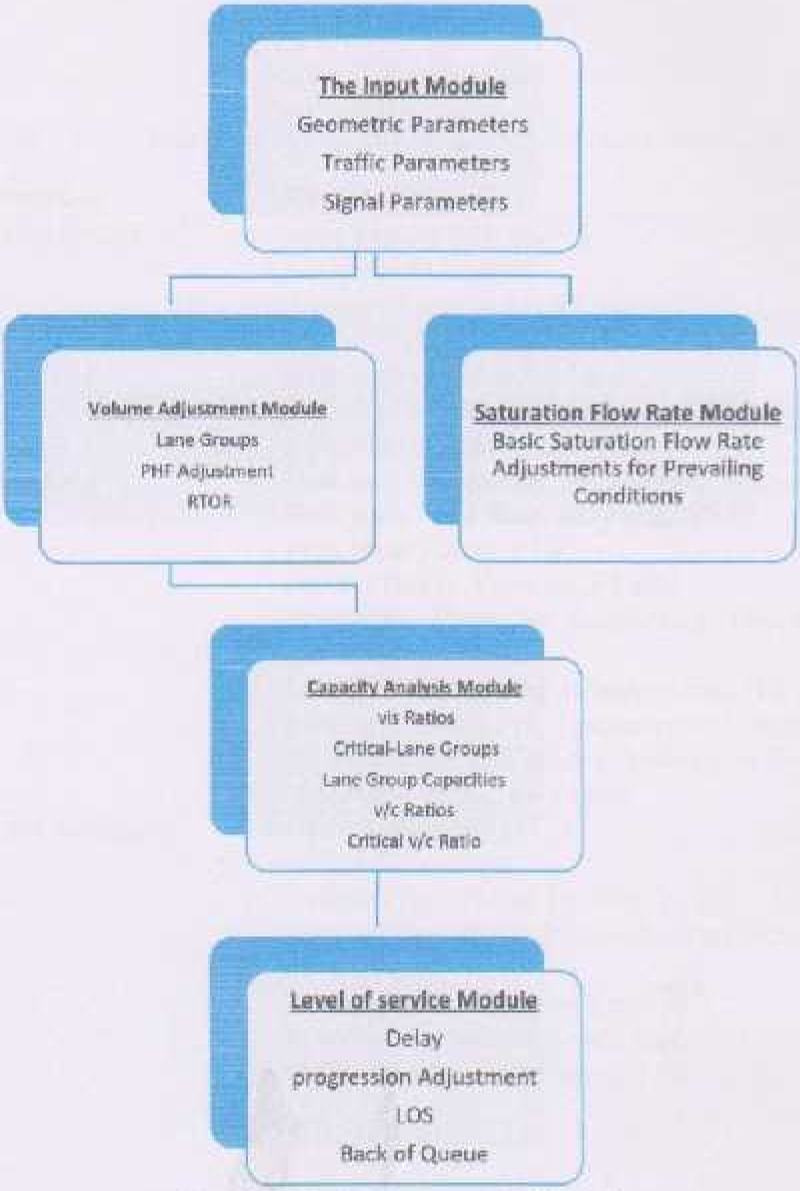


Figure 2. 5: The basic structure of HCM model

2.3.9 Data Requirements for Each Lane Group in Signalized Intersection Analysis

Table 2. 5: Data Requirements for Each Lane Group in Signalized Intersection Analysis

Types of Condition	Parameter
Geometric Conditions	Area Type (CBD, Other) Number of Lanes, N Average Lane Width, W (ft) Grade, G (%) Existence of LT or RT Lanes Length of Storage Bay for LT or RT lane (ft) Parking Conditions (Yes/No)
Traffic Conditions	Demand Volume by Movement, V (veh/h) Base Saturation Flow Rate, so (pc/hg/ln) Peak Hour Factor, PHF Percent Heavy Vehicles, PT (%) Pedestrian Flow in Conflicting Crosswalk, vp (peds/h) Local Buses Stopping at Intersection, NB (buses/h) Parking Activity, N, (maneuvers/h) Arrival Type, AT Proportion of Vehicles Arriving on Green, P Approach Speed, SA (mi/h)
Signalization Conditions	Cycle Length, C (s) Green Time, G (s) Yellow Plus All-Red Interval, Y (s) Type of Operation (Pretimed, Semi-Actuated, Full Actuated) Pedestrian Push Button (Yes/No) Minimum Pedestrian Green, G, (s) Phase Plan Analysis Period, T (h)

2.3.10 Capacity Analysis Module

In the Volume Adjustment Module, lane groups were established, as were demand flow rates, v, for each lane group. In the Saturation Flow Rate Module, the saturation flow rate, s, for each lane group has been estimated. Now, both the demand and saturation flow rates for each lane group have been adjusted to reflect the same prevailing conditions. At this point, the ratio of v to s for each lane group can be computed. It is now used as the variable indicating the relative demand intensity on each lane group.

In the Capacity Analysis Module, several important analytic steps are accomplished:

1. The v/s ratio for each lane group is computed.
2. Relative vls ratios are used to identify the critical lane groups in the phase plan; the sum of critical lane group v/s ratios is computed.
3. Lane group capacities are computed.
4. Lane group v/c ratios are computed.
5. The critical vlc ratio for the intersection is computed.

2.3.11 Level-of-Service Module

Levels of service are based on delay. In the capacity analysis module, values of the v/c ratio for each lane group will have been established. Using these results, and other signalization information, the delay for each lane group may be computed as:

$$d = d_1 PF + d_2 + d_3 \qquad (2.9)$$

Where: d = average control delay per vehicle, s/veh

d_1 = average uniform delay per vehicle, s/veh

PF = progression adjustment factor

d_3 = additional delay per vehicle s/veh

PF = additional delay per vehicle due to a preexisting queue, s/veh

Uniform Delay

Uniform delay is obtained using webster's uniform delay equation in the following form:

$$d_1 = \frac{0.5C[1-{}^{g}/_{c}]^2}{1-[\min(1,x)\cdot\left(\frac{g}{C}\right)]} \qquad (2.9.1)$$

Where: C = cycle length, s

g = effective green time for lane group, s

X = v/c ratio for lane group (max value =1)

Incremental Delay

The incremental-delay equations is based on Akcelik's equation and includes incremental delay from random arrivals as well as overflow delay when v/s ratio >1.00. It's estimated as:

$$d_2 = 900T[(X-1) + \sqrt{(X-1)^2 + \frac{8kIX}{cT}} \qquad (2.9.2)$$

Where: T = analysis time period, h

X = v/c ratio for lane group

c = capacity of lane group, veh/h

k = adjustment factor for type of controller

I = upstream filtering/metering adjustment factor

Initial Queue Delay

$$d_3 = \frac{1800Q_b(1+u)t}{cT} \qquad (2.9.3)$$

Where: Qb = size of initial queue at start of analysis period T,veh

c = capacity of lane group, veh/h

T = analysis period, h

t = duration of oversaturation within T,h

u = delay parameter

(Refer to Traffic Engineering text book P.Roess for more details)

2.3.12 Crash Data

Another important aspect of designing an intersection is the collection of crash data. This is the basis for safety analyses. Collision diagrams are made with accident reports that show which types of intersection occur, what the problem regions of an intersection are, and the overall frequency of crashes that occur. These are then referred to in an analysis of the data that includes calculations of crash rates and other similar statistics. We have visited the police department in 4/3/2014 and they assured us that the happy bunny intersection is not safe and lots of accidents happen there.

2.4 AASHTO & HCM 2010

Through this project, there are a series of important resources that have been referenced. All procedures and designs outlined in this report conform to the standards set by transportation organizations. Regulations set forth by AASHTO and HCM 2010, publications are referenced. In addition to these references, the text books of **Traffic & Highway Engineering** 4th Edition by Garber & Hoel, and **Traffic Engineering** (4th Edition) by P. Roess, S. Prassas and R. McShane are in use.

2.5 Design Alternatives

In order to discover alternative designs, the program Syncro 9 and vissim used to determine the level of service improvement for different alternatives. Different kinds of changes in the intersections were examined, including:

- Signal Timing,
- Number of lanes and
- Geometry of the intersection

2.6 Microsimulation

The psycho-physical car-following model by Prof.Rainer Wiedemann was developed at Karlsruhe of Technology in 1974 and 1999. It describes the movement of traffic on a single lane. The model is implemented in the PVT Vissim simulation and can be adjusted by the user via parameters in line with local conditions.

The Modeling of driving behavior is the core of traffic simulation. Vehicle movement models are a key element in being able to replay dynamics in a realistic manner.

The vehicle following model describes 4 states:

1. Free driving: The driver at this or her desired speed provided there are no obstacles in front of him or her. Such obstacles may include for example

slow moving vehicles, red traffic lights or potential collisions with vehicles changing lanes.

2. Approaching: The driver recognizes that there is a slow moving vehicle in front of him or her and brakes within the desired gap. In PVT Vissim, it is possible to define different driver and vehicle characteristics for different vehicle classes and types, such as the rate of deceleration when approaching the vehicle in front.
3. Following: The driver tries to maintain his or her distance from the vehicle in front when following it. However, the distance between the two vehicles oscillates -sometimes the speed is slightly higher, sometimes lover
4. Braking: If a vehicle reduces its speed downstream, then the vehicle behind must also brake. For each vehicle, vissim checks in each simulation time step the distance and the difference in speed in relation to the vehicle in front.

Lane changing, there are two different types of lane changing:

1. Free lane changing: Free lane changing takes place when over taking slow moving vehicles, i.e. when an individual's desired speed higher than the person in front. Attention must be paid to ensure that vehicles in the other lane are not unduly affected by this.
2. Necessary lane changing: This occurs if the driver needs to change lane e.g. in order to follow a route. The closer the driver gets to the decision making point, the more aggressively the driver behaves and is prepared to accept the hindrances posed by other drivers. Other vehicles also co-operate in order to allow the driver to change lanes.

Lateral behavior within a lane: The choice of position within a lane is always important if vehicles are able to overtake each other within a particular lane and are able to be side by side. This is the case on cycle paths or on regular streets in certain regions, for example.

The following pictures show shots of the happy bunny intersection in microsimulation:

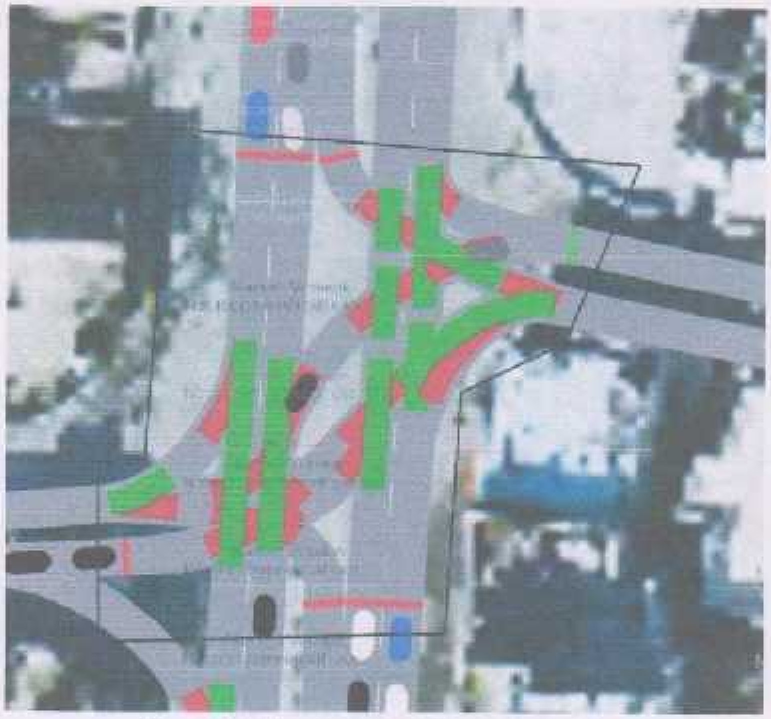


Figure 2. 6: Microsimulation of the existing conditions

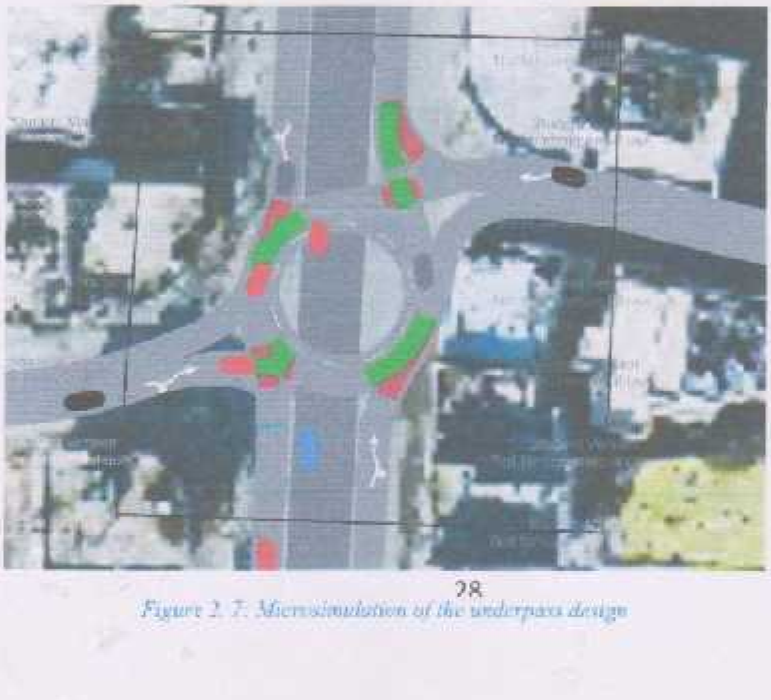


Figure 2. 7: Microsimulation of the underpass design

CHAPTER THREE

Methodology

Chapter 3: Methodology

The mechanism of work data that was collected for this project is presented in this chapter. Much of the data has been gathered by visiting the intersection site. The following data are discussed in the following sections in this chapter.

- Traffic volumes
- PHF
- General observations and
- Issues that affect re-design.

3.1 Counting and peak hour factor.

The most important data collected on-site by setting four people on the four sides of the intersection and manual counting. This data presents a complete picture of the trends and patterns in the current intersections and are used in the design process.

We have counted for three days spread throw the week in the morning and afternoon. The counting method was for 15 min count.

The entire set of volume data collected can be found in Appendix A: Traffic Volumes, but it is summarized in this section. Showing the maximum volumes and peak hour factor tables and charts of the intersection as the worst scenario.

➢ Maximum Morning Traffic volumes and Peak hour Factor

Table 3. 1. Maximum morning volumes and peak hour factor

Maximum Morning																		
	Intersection Eastbound				Intersection Northbound				Intersection Southbound				Intersection Westbound				Total Traffic	
Time	Right	Through	Left	Total	Right	Through	Left	Total	Right	Through	Left	Total	Right	Through	Left	Total		
7:00 - 7:15	9	19	15	43	4	147	17	168	12	170	25	207	11	10	8	29	447	
7:15 - 7:30	12	20	19	51	5	159	18	182	13	190	29	232	19	14	10	43	508	
7:30 - 7:45	31	45	45	121	8	219	29	256	25	267	49	341	35	25	22	83	801	
7:45 - 8:00	24	48	33	105	3	203	19	225	33	237	57	327	43	50	20	113	770	2526
8:00 - 8:15	12	35	17	64	6	180	7	193	17	227	54	298	41	30	16	87	642	2721
8:15 - 8:30	16	20	17	53	5	184	10	199	14	167	34	215	13	16	15	44	511	2724
8:30 - 8:45	5	10	13	28	5	165	15	185	10	202	32	244	9	16	9	34	491	2414
8:45 - 9:00	8	18	22	48	3	164	15	182	12	209	24	245	11	21	12	44	519	2163
9:00 - 9:15	12	14	26	52	7	196	8	211	18	228	28	274	10	15	13	38	575	2096
9:15 - 9:30	9	17	20	46	6	193	12	211	21	193	30	244	9	21	8	38	539	2124
9:30 - 9:45	10	18	28	56	4	179	7	190	15	216	38	270	13	19	17	49	565	2198
9:45 - 10:00	10	21	24	55	5	178	16	199	20	209	24	253	15	17	10	42	549	2228
	83	148	112		22	786	65		89	838	194		132	122	73			
	Peak Hour Total:			343	Peak Hour Total:			873		Peak Hour Total:		1181		Peak Hour Total:		327		
			PHF:	0.7086777			PHF:	0.8525391			PHF:	0.86583578			PHF:	0.72345133	PHF:	0.88344156

➢ Maximum Afternoon Traffic volumes and Peak hour Factor

Table 3. 2: Maximum morning volumes and peak hour factor

Maximum Afternoon																		
	Intersection Eastbound				Intersection Northbound				Intersection Southbound				Intersection Westbound				Total Traffic	
Time	Right	Through	Left	Total	Right	Through	Left	Total	Right	Through	Left	Total	Right	Through	Left	Total		
7:00 - 7:15	11	28	33	72	9	178	10	197	14	231	33	278	10	18	22	50	597	
7:15 - 7:30	14	22	27	63	4	191	9	204	19	195	42	256	10	20	21	51	574	
7:30 - 7:45	10	34	39	83	4	175	13	192	15	202	41	258	16	25	29	70	603	
7:45 - 8:00	10	28	43	81	10	163	9	182	19	182	39	240	14	27	31	72	575	2349
8:00 - 8:15	8	27	44	79	8	167	12	187	20	193	40	253	17	37	28	82	601	2353
8:15 - 8:30	12	38	42	92	6	207	7	220	21	189	45	256	16	25	17	58	626	2405
8:30 - 8:45	15	43	46	104	10	178	9	197	24	196	49	269	23	29	30	82	652	2454
8:45 - 9:00	18	32	47	97	6	177	13	196	28	200	42	270	20	26	18	64	627	2506
9:00 - 9:15	20	35	31	86	7	197	15	219	27	186	45	258	16	32	28	76	639	2544
9:15 - 9:30	20	38	52	110	9	203	13	225	30	188	50	268	16	25	32	73	675	2594
9:30 - 9:45	16	37	37	90	6	195	15	216	30	168	38	236	17	26	27	70	612	2554
9:45 - 10:00	17	41	36	94	8	206	16	230	29	217	42	288	18	33	22	73	685	2612
	73	151	156		30	801	59		116	759	175		57	116	109			
		Peak Hour Total:		380		Peak Hour Total:		890		Peak Hour Total:		1030		Peak Hour Total:		292		
			PHF:	0.8636364			PHF:	0.9673913			PHF:	0.91145833			PHF:	0.96052632	PHF:	0.95328467

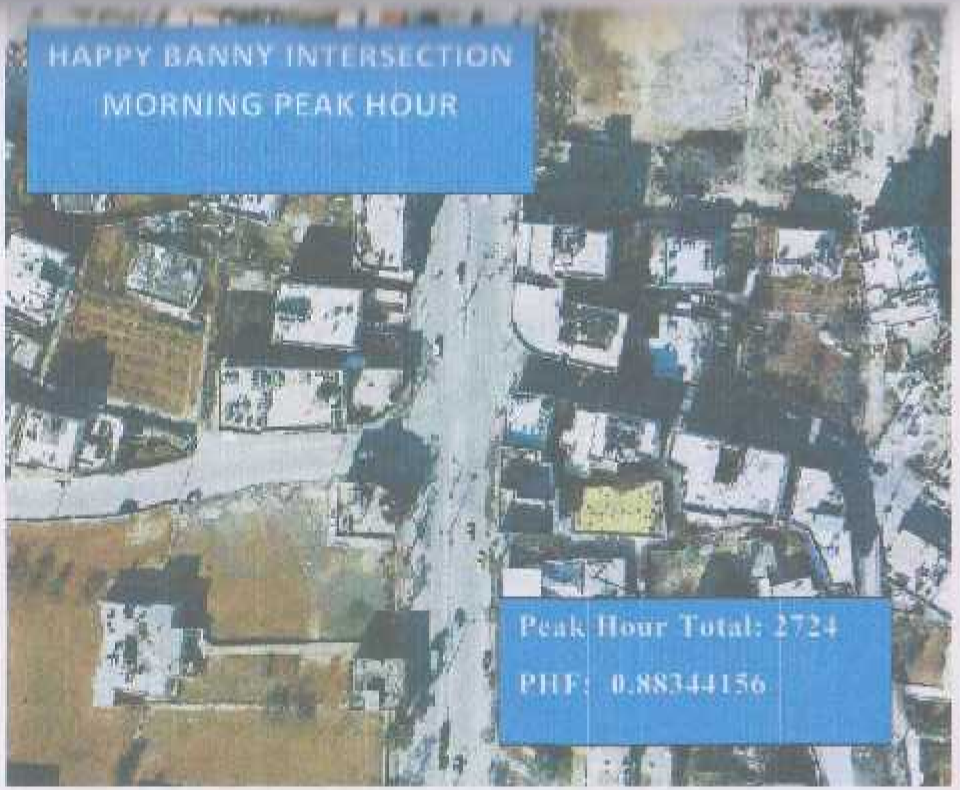


Figure 3. 1: Intersection max morning peak hour

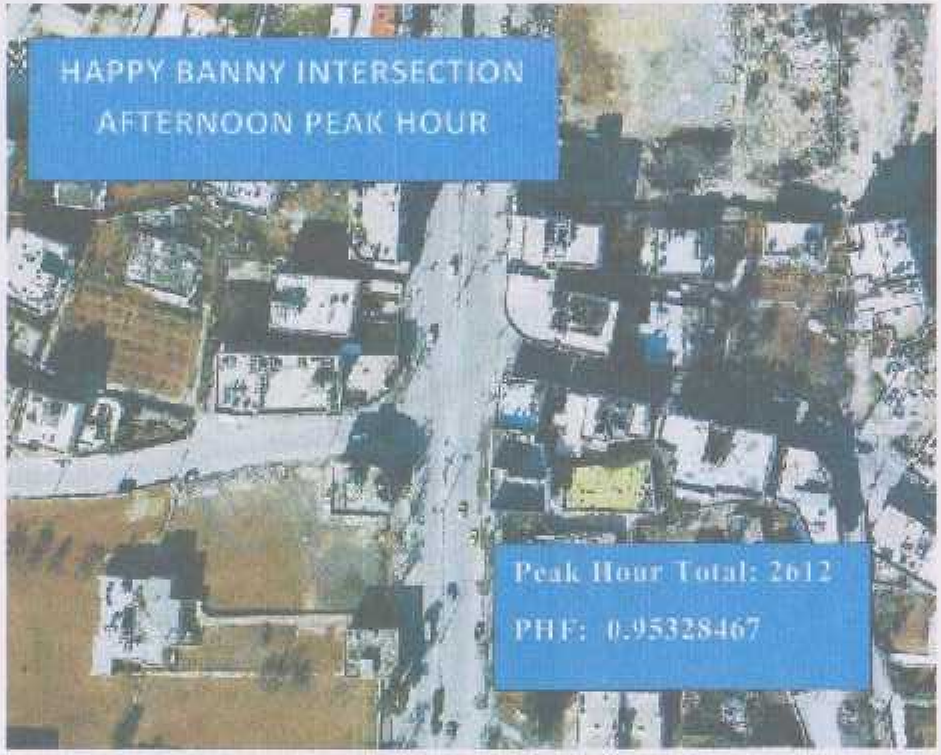


Figure 3. 2: Intersection max afternoon peak hour

Figure 3. 3: Morning Maximum Volumes and PHF North approach

Table 3. 3: Morning Maximum Volumes North approach

Approach	North		
Type of Data	MAX		
Time	Right	Through	Left
7:10 - 7:15	4	147	17
7:15 - 7:30	5	159	18
7:30 - 7:45	8	219	29
7:45 - 8:00	3	203	19
8:00 -8:15	6	180	7
8:15 - 8:30	5	184	10
8:30 - 8:45	5	165	15
8:45 - 9:00	3	164	15
9:00 - 9:15	7	196	8
9:15 - 9:30	6	193	12
9:30 - 9:45	4	179	7
9:45 -10:00	5	178	16

Figure 3. 5: Morning maximum volumes north approach right turn

Figure 3. 4: Morning maximum volumes north approach through

Figure 3. 6: Morning maximum volumes north approach left turn

Figure 3. 7: Afternoon maximum volumes and PHF north approach

Table 3. 4: Afternoon maximum volumes north approach

Approach	North		
Type of Data	MAX		
Time	Right	Through	Left
11:00 - 11:15	9	178	10
11:15 - 11:30	4	191	9
11:30 - 11:45	4	175	13
11:45 -12:00	10	163	9
12:00 -12:15	8	167	12
12:15 -12:30	6	207	7
12:30 -12:45	10	178	9
12:45 -13:00	6	177	13
13:00 -13:15	7	197	15
13:15 -13:30	9	203	13
13:30 -13:45	6	195	15
13:45 - 14:00	8	206	16

Figure 3. 8: Afternoon maximum volumes north approach right turn

Figure 3. 9: Afternoon maximum volumes north approach through

Figure 3. 10: Afternoon maximum volumes north approach left turn

Figure 3. 12: Morning maximum volumes and PHF south approach

Table 3. 5: Morning Maximum Volumes south approach

Approach	South		
Type of Data	MAX		
Time	Righ	Through	Left
7:10 - 7:15	12	170	25
7:15 - 7:30	13	190	29
7:30 - 7:45	25	267	49
7:45 - 8:00	33	237	57
8:00 -8:15	17	227	54
8:15 - 8:30	14	167	34
8:30 - 8:45	10	202	32
8:45 - 9:00	12	209	24
9:00 - 9:15	18	228	28
9:15 - 9:30	21	193	30
9:30 - 9:45	16	216	38
9:45 -10:00	20	209	24

Figure 3. 13: Morning maximum volumes south approach right turn

Figure 3. 15: Morning maximum volumes south approach left turn

Figure 3. 14: Morning maximum volumes south approach through

Figure 3. 16: Afternoon maximum volumes and PHF south approach

Table 3. 6: Afternoon Maximum Volumes South approach

Approach	South		
Type of Data	MAX		
Time	Right	Through	Left
11:00 - 11:15	14	231	33
11:15 - 11:30	19	195	42
11:30 - 11:45	15	202	41
11:45 -12:00	19	182	39
12:00 -12:15	20	193	40
12:15 -12:30	21	189	46
12:30 -12:45	24	196	49
12:45 -13:00	28	200	42
13:00 -13:15	27	186	45
13:15 -13:30	30	188	50
13:30 -13:45	30	168	38
13:45 - 14:00	29	217	42

Figure 3. 17: Afternoon maximum volumes south approach right turn

Figure 3. 18: Afternoon maximum volumes south approach through

Figure 3. 19: Afternoon maximum volumes south approach left turn

Figure 3. 20: Morning maximum volumes and PHF east approach

Table 3. 7: Morning maximum Volumes east approach

Approach	East		
Type of Data	MAX		
Time	Right	Through	Left
7:10 - 7:15	9	19	15
7:15 - 7:30	12	20	19
7:30 - 7:45	31	45	45
7:45 - 8:00	24	48	33
8:00 -8:15	12	35	17
8:15 - 8:30	16	20	17
8:30 - 8:45	5	10	13
8:45 - 9:00	8	18	22
9:00 - 9:15	12	14	26
9:15 - 9:30	9	17	20
9:30 - 9:45	10	18	28
9:45 -10:00	10	21	24

Figure 3. 21: Morning maximum volumes east approach right turn

Figure 3. 22: Morning maximum volumes east approach through

Figure 3. 23: Morning maximum volumes east approach left turn

Figure 3. 24: Afternoon maximum volumes and PHF east approach

Table 3. 8. Afternoon maximum Volumes east approach

Approach	East		
Type of Data	MAX		
Time	Right	Through	Left
11:00 - 11:15	11	28	33
11:15 - 11:30	14	22	27
11:30 - 11:45	10	34	39
11:45 -12:00	10	28	43
12:00 -12:15	8	27	44
12:15 -12:30	12	38	42
12:30 -12:45	16	43	45
12:45 -13:00	18	32	47
13:00 -13:15	20	35	31
13:15 -13:30	20	38	52
13:30 -13:45	16	37	37
13:45 - 14:00	17	41	36

Figure 3. 26: Afternoon maximum volumes east approach right turn

Figure 3. 27: Afternoon maximum volumes east approach left turn

Figure 3. 25 : Afternoon maximum volumes east approach through

Figure 3. 28: Morning maximum volumes and PHF west approach

Table 3. 9:Morning maximum volumes west approach

Approach	West		
Type of Data	MAX		
Time	Righ	Through	Left
7:10 - 7:15	11	10	8
7:15 - 7:30	19	14	10
7:30 - 7:45	35	26	22
7:45 - 8:00	43	50	20
8:00 -8:15	41	30	16
8:15 - 8:30	13	16	15
8:30 - 8:45	9	16	9
8:45 - 9:00	11	21	12
9:00 - 9:15	10	15	13
9:15 - 9:30	9	21	8
9:30 - 9:45	13	19	17
9:45 -10:00	15	17	10

Figure 3. 29:Morning maximum volumes west approach right turn

Figure 3. 31: Morning maximum volumes west approach left turn

Figure 3. 30: Morning maximum volumes west approach through

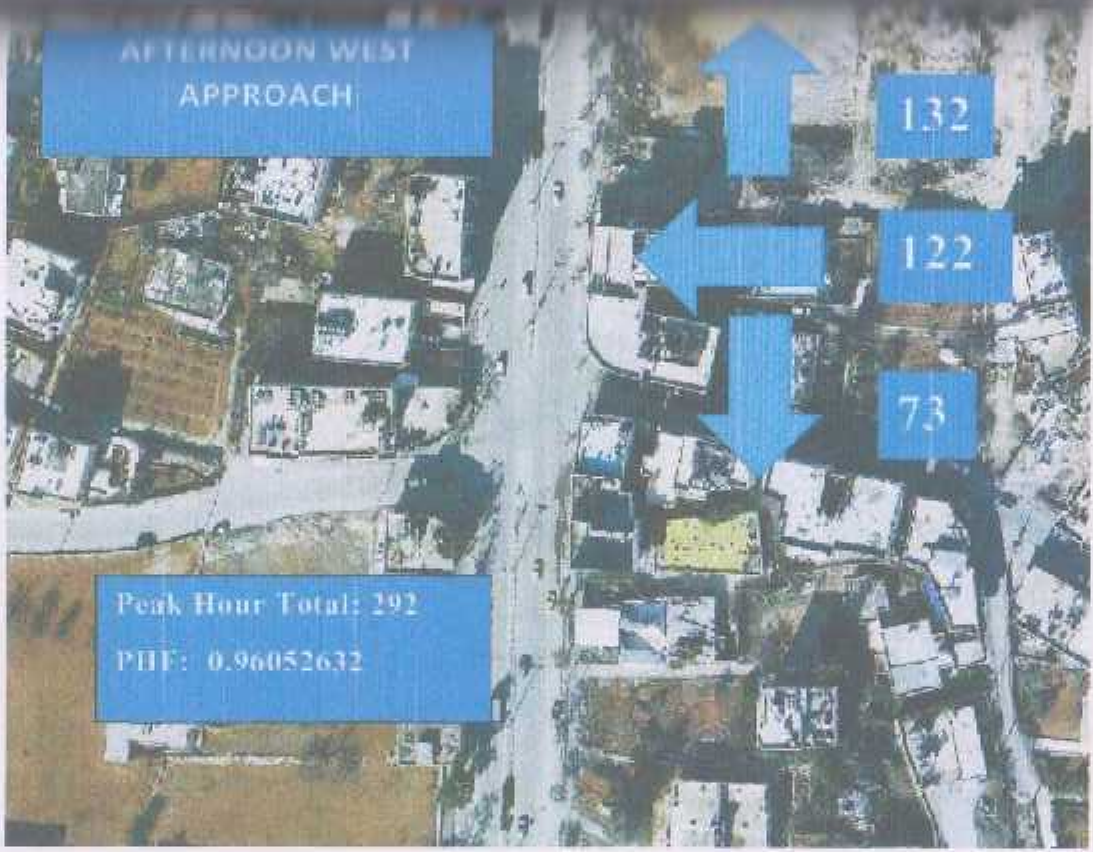


Figure 3. 32: Afternoon maximum volumes and PHF west approach

Table 3. 10: Afternoon maximum volumes west approach

Approach	West		
Type of Data	MAX		
Time	Right	Through	Left
11:00 - 11:15	10	18	22
11:15 - 11:30	10	20	21
11:30 - 11:45	16	25	29
11:45 -12:00	14	27	31
12:00 -12:15	17	37	28
12:15 -12:30	16	25	17
12:30 -12:45	23	29	30
12:45 -13:00	20	26	18
13:00 -13:15	16	32	28
13:15 -13:30	16	25	32
13:30 -13:45	17	26	27
13:45 - 14:00	18	33	22

Figure 3. 33: Afternoon maximum volumes west approach right turn

Figure 3. 35: Afternoon maximum volumes west approach left turn

Figure 3. 34: Morning maximum volumes west approach through

3.3 General Observations

The general observations that were noted during visits to the intersection include:

- Types of traffic using the intersection,
- Signal Timing.

3.3.1 Traffic operations

As noticed from the previous tables, the majority of the traffic traveling through the intersection during the peak hours was going north towards "Ra's Al-Jorh" and south towards the center of the city. This is why many of the drivers who use this intersection are assumed to be commuters going to and from their workplaces. School buses were another common type of vehicle which uses this intersection, as were students commuting to the schools and colleges of the region (i.e., Palestine polytechnic University and Hebron University). Other types of vehicles seen using these intersections included dump trucks, trailers and general heavy trucks, but they were not overly prevalent. In addition, there were a number of businesses in the area including stores and restaurants. These businesses were also common destinations for passenger vehicles travelling in the area. The majority of the vehicles at these intersections were cars, light trucks, and vans.

The use of the crosswalks by the pedestrians was also observed. Unfortunately, there is a lack of awareness by the people of Hebron city, where there is almost no one use the cross walks. However, there was never more than one per hour to cross from the cross walk. Also, there was greater pedestrian traffic in the afternoon than in the morning, even though they were crossing from the middle of the street. The pedestrian traffic was neglected during the analysis of the intersections.

3.3.2 Signal Timing

The signal timing was the most important aspect of the intersection that was studied, and was the main design aspect of the possible re-designs. Signal timing is significant because it dictates how traffic flows through intersection. Unfortunately, not a piece of information was provided by city Municipal about how the signals are working or what are signal timing plans.

Observed signal timing

Some specific signal timing observations were made at around 5 P.M on Saturday evening and are summarized in the table below.

Table 3. 11: Observed signal timing

Phase	Approach	Green(S)	Yellow (S)
1	NBL & SBL	12.42	2.07
2	NBT,NBR,SBT &SBL	35.06	2.02
3	WB(T,L,R)	15.54	1.89
4	EB(T,L)	13.59	1.73

Note that there isn't any documented observation to compare with.

Existing conditions LOS Analysis

The result of analysis of the existing conditions:

Table 3. 12: Level of service existing conditions

Existing condition	EB	WB	NB	SB	Intersection
Delay (sec)	53	75.8	33.6	52.5	47.9
LOS	D	E	C	D	D

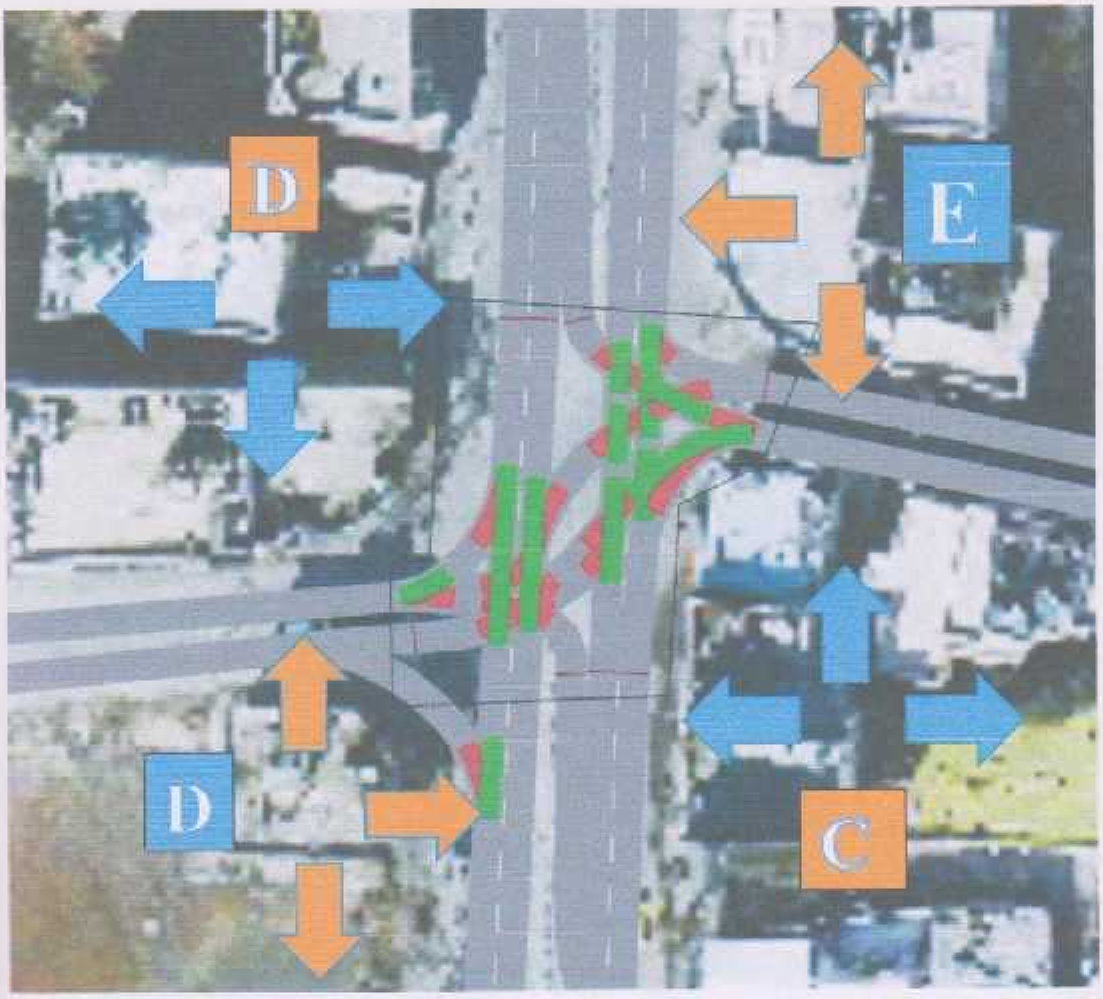


Figure 3. 36: Level of service existing conditions with conflict areas

3.4 Issues That Affect Re-Design

There are some characteristics of the site that must be taken into account in analyzing the possible redesigns of the intersections. These physical barriers challenge the implementation of major re-designs at this intersection.

3.4.1 The geometry and the buildings surrounding

The bad geometry of the intersection affect the level of service and it will be hard to change the geometry because of the buildings around the intersection.

3.3.2 The traffic in Ein sara street

In this project we consider that Ein Sara Street is the vein of Hebron city. So any construction in the area of the intersection will affect the whole movement from and into the center of the city.

CHAPTER FOUR

Design Alternative

Chapter Four: Design Alternatives

The design process for the Happy Bunny intersection conducted with the goal of improving the level of service, flow, and overall functionality of this complex intersection. This process begin by identifying several possible alternatives the alternatives to see which would make the largest improvement. The alternatives for designing the intersection considered are the following:

- Signal timing changes,
- Changing the whole geometry of the intersection by developing a multilevel.

4.1 Signal timing optimizing

The first possible alternative of re-designing the intersection is Signal timing optimizing. This is the most preferable form of Intersection change because it doesn't need construction and takes almost no money to accomplish compared to other types of changes. The only cost is the time it takes for the municipality employee already on payroll to go to the signal controls on site and change the signal times. The optimizing of signal timing possibilities, and the overall evaluation of the intersection was done using the programs syncro 9 and vissim 7 for Signals optimizing, which is used to calculate the level of service of intersections. This application uses multiple Signals controller's files and analyzes how they function in conjunction with one another.

Decreasing and increasing the Overall Cycle Length

While changing the signal timings would have been the best option economically, it is a very difficult solution to achieve with the circumstances of the intersection. If any change was made to the intersection timings that compromised the ratios between each of the directions, the overall level of service for the intersection decreased dramatically. The only changes that improved the intersection were to decrease the overall signal times of each phase at the happy bunny intersection by a percentage. This change does two things in theory: first, it decreases the total delay for each approach, and second, it decreases the maximum queue length in all approach, in our case we have decreased cycle length from 96 s to 90 s.

Table, below, shows the level of service results of changing cycle length from 96 to 90 s. When compared to the current level of service, it can be seen the tiny improvement in delay for all approaches as we see and we can notice that the signal timing in the happy bunny so critical.

Table 4-1: Comparison between level of service of existing conditions and optimized signal timing

Existing condition		EB	WB	NB	SB	Intersection
	Delay (sec)	53	75.8	33.6	52.5	47.9
	LOS	D	E	C	D	D
Optimized		EB	WB	NB	SB	intersection
	Delay (sec)	27.1	46.8	22.9	72.2	41
	LOS	C	D	C	E	D

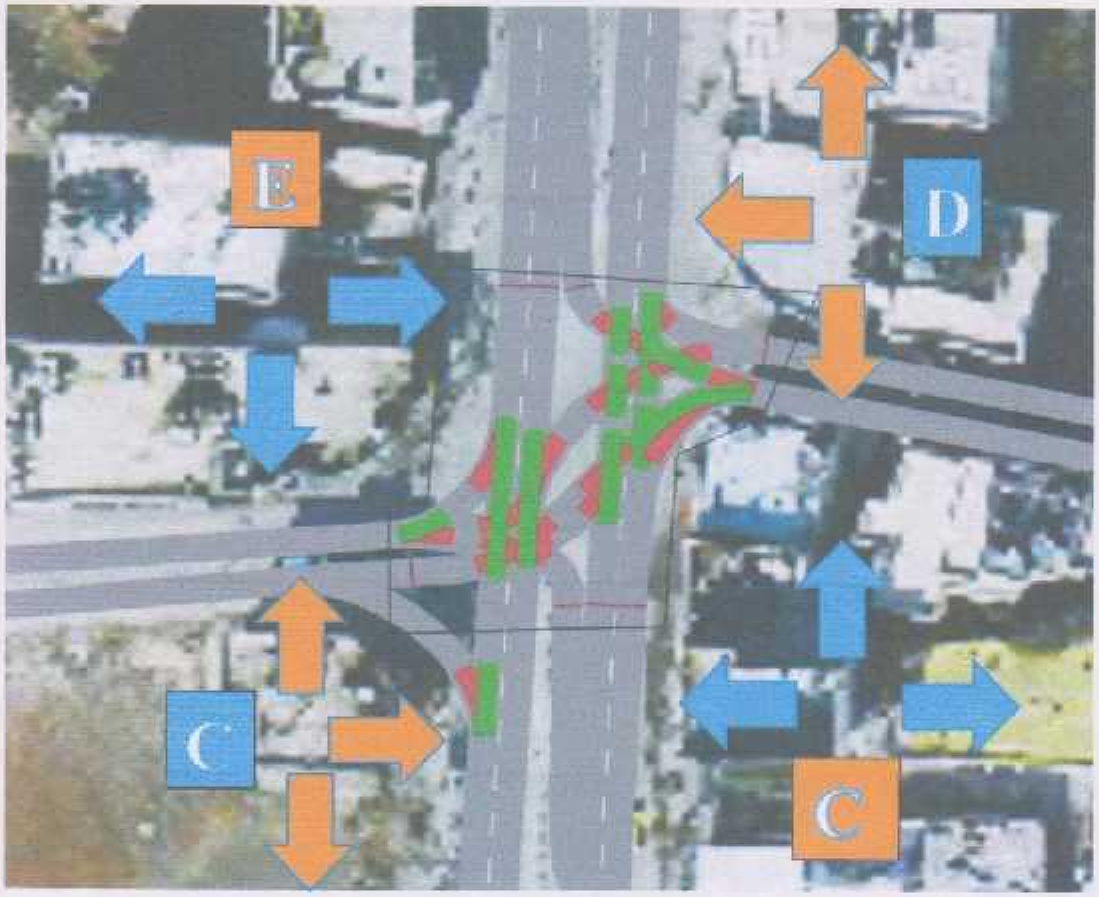


Figure 4. 1: Level of service of optimized signal timing

4.2 Overpass design

Rising traffic congestion is an inescapable condition in large and growing areas across the world. Peak-hour traffic congestion is an inherent result of the way modern societies operate. It stems from the increasing in population widespread desires of people to pursue certain goals that inevitably overload existing roads and transit systems every day. But everyone hates traffic congestion, and it keeps getting worse, in spite of attempted remedies.

Commuters are often frustrated by policymakers' inability to do anything about the problem, which poses a significant public policy challenge. Although councils may never be able to eliminate road congestion, there are several ways cities can move to curb it.

The population in Hebron has been increasing the last few years and so the traffic congestion throw peak hours. Here if we don't think in different way; looking for new creative solutions, Hebron center will be moved again away from the old center serving the ambitions of the occupation who is looking for Gaps to spread his domination in Hebron city.

From this point of view we managed to look into a different way of thinking to be applied in Hebron city to keep the wheel of life running in the center of this city.

The project will:

- Provide non-stop access between the South and north of the intersection
- Maintain local access to the area
- Improve traffic efficiency and safety
- Encourage and enhance walking, cycling and public transport options
- Enhance local access for the community
- Provide opportunities for urban, landscape and environmental improvements

Alternate Concept Scheme

- A roundabout in the level of the existing intersection connecting the minor streets with the major street.
- A lowered, non-stop motorway passing underneath the roundabout with one lane to the north and another to the south
- Main Road (at grade) service roads along both sides of the lowered motorway to provide connections to the roundabout.
- Enhanced overall traffic performance with the majority of traffic wanting to pass through the local area able to do so through the motorway, leaving only local traffic using Main street (at grade) service roads
- Improved safety for pedestrians and cyclists due to Main Road (at grade) being positioned on the outside of the motorway, resulting in smaller, staged intersections and crossing points
- No impact to Main Road Intersection. The design has taken into consideration the future transport needs of other intersection and allows for connection to the next stage of upgrade in the future.

Table, below, shows the level of service results of Changing the whole geometry of the intersection by developing a multilevel intersection consist of a roundabout and underpass. When compared to the current level of service, it can be seen the huge improvement in the level of service for all approaches and this would be a long term solution implement a new era of highway design in Hebron City and other Palestinian cities.

Table 4. 2: Existing conditions level of service

Existing condition	EB	WB	NB	SB	Intersection
Delay (sec)	53	75.8	33.6	52.5	47.9
LOS	D	E	C	D	D
ICU Level of Service					D

ICU: intersection capacity utility

In the design of the alternative the ICU level of service has increased to B for the Roundabout.

The underpass LOS is A with almost 0 delay. And these results serve the intersection for long period.

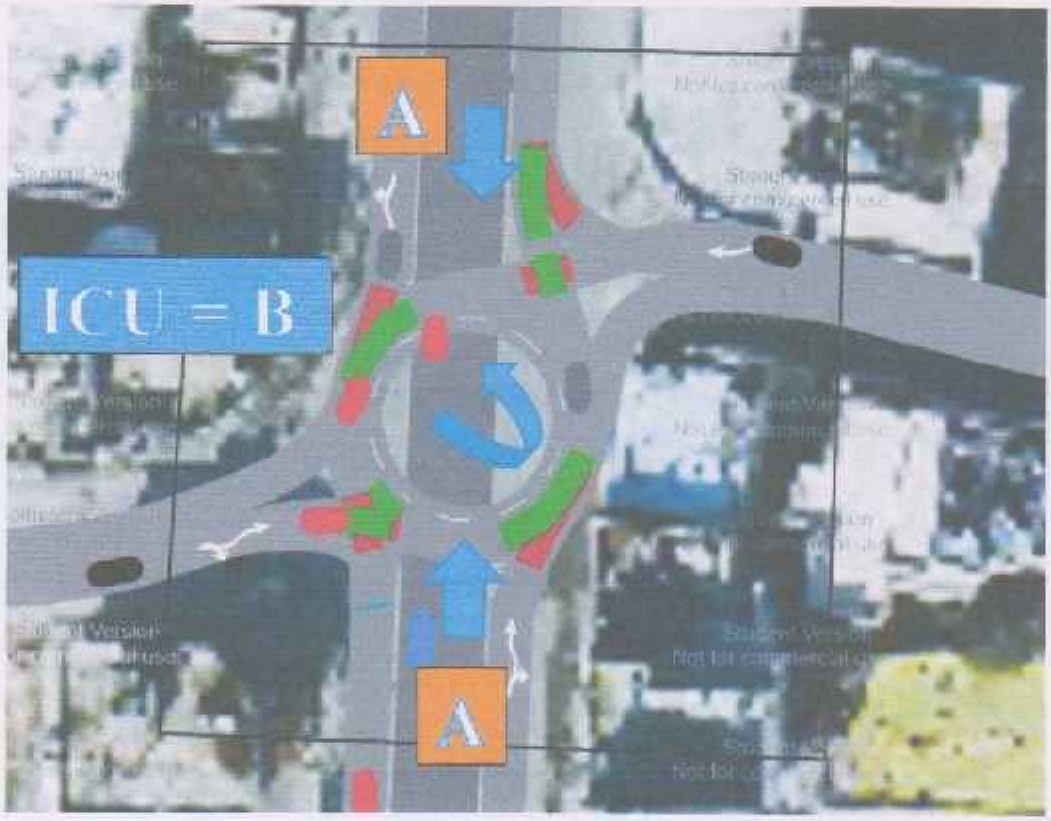


Figure 4. 2: Level of service of the underpass design

4.3 Conclusion & Recommendations

The recommended alternatives should be used to improve the intersections separately and the arterial as a whole. The goal is to increase safety, decrease queue lines, and improve the overall flow of both of the intersections. The recommendations consist of the most effective choices from the redesign alternatives section.

Recommendation #1 – Signal Timing (Short term solution)

The first of the recommendations is the signal timing which is discussed in detail in the design alternatives section. The initial changes made to the signal timing should include changing the timing from the current timing to eighty percent of the current timing. This would help decrease the queue lengths and improve the flow of traffic. The advantage of this alternative that it has no cost and doesn't need time to be applied. But this solution is for a short period like 4 or 5 years at max.

Recommendation #2 – Underpass Design (Long term solution)

The underpass is also an alternative that will be recommended for the improvements to the intersection. Provide non-stop access between the South and north of the intersection, Maintain local access to the area, Improve traffic efficiency and safety, encourage and enhance walking, cycling and public transport options, Enhance local access for the community, provide opportunities for urban, landscape and environmental improvements and compliment the culture and unique character. This alternative would solve the congestion in the intersection showing effective and safe results and for a long period. But with this effectiveness come high cost and and construction which will last for a year and that would affect economic in Ein Sara street

References

Books

[1] Roger P.Roess, Elena S.Prassas, William R.Mcshane Traffic Engineering, 4th edition (2010).

[2] Nicholas J.Garber, Lester A.Hoel Traffic & Highway Engineering, 4^{th} edition (2009).

[3] National research council, Highway capacity manual, 5^{th} edition (HCM2010).

[4] Tom V. Mathew and K V Krishna Rao Introduction to Transportation Engineering (2012)

[5] Bruce Hellinga, PhD, PEng and Zeeshan Abdy, Signalized Intersection Analysis and Design – Implications of Day-to-Day Variability in Peak

[6] Traffic engineering handbook / James L. Pline, editor. — 5th ed

[7] Downtown underpass urban design guidelines, Linking Downtown and Beltline NOVEMBER 2010

[8]Mike Slinn, Paul Matthews and Peter Guest Traffic Engineering Design 2^{nd} edition

[9] Coleman O'Flaherty, Transport Planning and Traffic Engineering 4^{th} edtion

[10] Kay Fitzpatrick, Mark D. Wooldridge, and Joseph D. Blaschke, URBAN INTERSECTION DESIGN GUIDELINES

Websites

[11] http://nacto.org/usdg/intersections/complex-intersections/ 1/12/2014

[12] http://travelpalestine.ps/hebron/ 3/2/2015

[13]http://azdot.gov/business/engineering-and-construction/traffic/traffic-engineering-references 21/4/2015

[14] http://www.dot.state.mn.us/trafficeng/publ/tem/ 5/5/2015

[15] http://safety.fhwa.dot.gov/intersection/alter_design/ 29/4/2015

APPENDICES

Appendices

Appendices

Appendix A: Traffic Volumes and Peak hour Factor calculations

A.1 Average morning Peak hour Factor calculations

Table A. 1: Average morning Peak hour Factor calculations

Average Morning																		
Intersection Eastbound				Intersection Northbound				Intersection Southbound				Intersection Westbound					Total Traffic	
Time	Right	Through	Left	Total	Right	Through	Left	Total	Right	Through	Left	Total	Right	Through	Left	Total		
7:00 - 7:15	5	11	9	25	3	104	9	116	6	117	16	139	7	7	6	20	300	
7:15 - 7:30	7	14	12	33	4	116	9	129	7	131	18	156	12	9	8	28	347	
7:30 - 7:45	20	26	27	73	4	168	17	189	14	209	31	254	20	16	17	53	569	
7:45 - 8:00	18	29	22	70	2	175	10	187	21	201	39	262	30	31	14	75	593	1809
8:00 - 8:15	10	25	13	47	3	161	5	170	12	190	40	242	24	18	9	51	510	2019
8:15 - 8:30	9	13	12	34	4	145	7	157	10	142	21	173	8	13	9	30	394	2066
8:30 - 8:45	4	9	10	23	3	157	9	170	6	174	21	201	7	10	6	23	417	1914
8:45 - 9:00	5	13	15	33	3	145	7	155	6	188	18	213	8	15	8	31	431	1752
9:00 - 9:15	7	13	18	38	3	175	5	183	10	201	23	234	7	10	10	27	483	1726
9:15 - 9:30	6	13	16	35	4	161	7	172	10	179	22	211	7	15	7	29	445	1777
9:30 - 9:45	7	15	16	39	2	160	5	167	10	194	26	230	11	17	10	37	473	1833
9:45 - 10:00	9	14	18	41	3	175	10	188	11	186	22	219	12	15	10	36	485	1887
	57	94	74		13	650	39		56	742	132		82	78	49			
	Peak Hour Total:			224	Peak Hour Total:			703	Peak Hour Total:			931	Peak Hour Total:			209		
			PHF:	0.7647727			PHF:	0.9294533			PHF:	0.88917197			PHF:	0.69856071	PHF:	0.85103991

A.2 Average Afternoon Peak hour Factor calculations

Table A. 2: Average Afternoon Peak hour Factor calculations

Average Afternoon																		
Intersection Eastbound				Intersection Northbound				Intersection Southbound				Intersection Westbound					Total Traffic	
Time	Right	Through	Left	Total	Right	Through	Left	Total	Right	Through	Left	Total	Right	Through	Left	Total		
7:00 - 7:15	6	17	19	42	5	168	8	180	8	197	25	231	8	18	13	39	492	
7:15 - 7:30	11	20	19	50	2	183	8	193	10	185	34	229	10	16	11	37	510	
7:30 - 7:45	7	24	22	54	3	170	11	183	10	184	34	228	10	21	16	47	511	
7:45 - 8:00	9	20	22	52	7	157	6	170	11	174	30	216	11	24	17	53	490	2004
8:00 - 8:15	6	22	27	55	5	157	9	171	12	161	35	208	12	25	16	53	486	2000
8:15 - 8:30	12	25	22	58	5	184	6	195	16	180	40	236	16	23	15	54	543	2033
8:30 - 8:45	14	28	25	67	6	166	8	181	15	174	40	230	15	22	17	54	531	2053
8:45 - 9:00	13	20	25	59	6	166	11	183	21	186	33	239	21	23	12	56	537	2100
9:00 - 9:15	15	27	22	64	5	178	12	195	19	174	35	228	19	25	15	60	546	2158
9:15 - 9:30	16	31	32	79	7	176	12	196	21	174	35	230	21	24	17	61	566	2181
9:30 - 9:45	13	27	24	64	5	176	10	191	17	155	34	206	17	24	17	58	519	2168
9:45 - 10:00	13	32	22	67	5	178	13	196	19	190	32	241	19	27	17	63	568	2199
	58	115	100		23	708	47		77	692	135		77	100	66			
	Peak Hour Total:			274	Peak Hour Total:			778	Peak Hour Total:			904	Peak Hour Total:			242.566567		
			PHF:	0.8634454			PHF:	0.9906621			PHF:	0.93775934			PHF:	0.95789474	PHF:	0.96036406

A.3 Maximum Morning Peak hour Factor calculations

Table 4. 3: Maximum Morning Peak hour Factor calculations

Maximum Morning																		
	Intersection Eastbound				Intersection Northbound				Intersection Southbound				Intersection Westbound				Total Traffic	
Time	Right	Through	Left	Total	Right	Through	Left	Total	Right	Through	Left	Total	Right	Through	Left	Total		
7:00 - 7:15	9	29	15	43	4	147	17	168	12	170	25	207	11	10	8	29	447	
7:15 - 7:30	12	20	19	51	5	159	18	182	13	190	29	232	19	14	10	43	508	
7:30 - 7:45	31	45	45	121	8	219	29	256	25	267	49	341	35	26	22	83	801	
7:45 - 8:00	24	48	33	105	3	203	19	225	33	237	57	327	43	50	20	113	770	2525
8:00 - 8:15	12	35	17	64	6	180	7	193	17	227	54	298	41	30	16	87	642	2721
8:15 - 8:30	16	20	17	53	5	184	10	199	14	167	34	215	13	16	15	44	511	2724
8:30 - 8:45	5	10	13	28	5	165	15	185	10	202	32	244	9	16	9	34	491	2414
8:45 - 9:00	8	18	22	48	3	164	15	182	12	209	24	245	11	21	12	44	519	2163
9:00 - 9:15	12	14	26	52	7	196	8	211	18	228	28	274	10	15	13	38	575	2095
9:15 - 9:30	9	17	20	46	6	193	12	211	21	193	30	244	9	21	8	38	539	2124
9:30 - 9:45	10	18	28	56	4	179	7	190	16	216	38	270	13	19	17	49	565	2198
9:45 - 10:00	10	21	24	55	5	178	16	199	20	209	24	253	15	17	10	42	549	2228
	83	148	112		22	786	65		89	898	194		132	122	73			
	Peak Hour Total:			343	Peak Hour Total:			873		Peak Hour Total:		1181		Peak Hour Total:		327		
			PHF:	0.7086777			PHF:	0.8525391			PHF:	0.86583578			PHF:	0.72345133	PHF:	0.88344156

A.4 Maximum Afternoon Peak hour Factor calculations

Table A. 4. Maximum Afternoon Peak hour Factor calculations

Maximum Afternoon																		
	Intersection Eastbound				Intersection Northbound				Intersection Southbound				Intersection Westbound				Total Traffic	
Time	Right	Through	Left	Total	Right	Through	Left	Total	Right	Through	Left	Total	Right	Through	Left	Total		
7:00 - 7:15	11	28	33	72	9	178	10	197	14	231	33	278	10	18	22	50	597	
7:15 - 7:30	14	22	27	63	4	191	9	204	19	195	42	256	10	20	21	51	574	
7:30 - 7:45	10	34	39	83	4	175	13	192	15	202	41	258	16	25	29	70	603	
7:45 - 8:00	10	28	43	81	10	163	9	182	19	182	39	240	14	27	31	72	575	2349
8:00 - 8:15	8	27	44	79	8	167	12	187	20	193	40	253	17	37	28	82	601	2353
8:15 - 8:30	12	38	42	92	6	207	7	220	21	189	46	256	16	25	17	58	626	2405
8:30 - 8:45	16	43	45	104	10	178	9	197	24	196	49	269	23	29	30	82	652	2454
8:45 - 9:00	18	32	47	97	6	177	13	196	28	200	42	270	20	26	18	64	627	2506
9:00 - 9:15	20	35	31	86	7	197	15	219	27	186	45	258	16	32	28	76	639	2544
9:15 - 9:30	20	38	52	110	9	203	13	225	30	188	50	268	16	25	32	73	676	2594
9:30 - 9:45	16	37	37	90	6	195	15	216	30	168	38	236	17	26	27	70	612	2554
9:45 - 10:00	17	41	36	94	8	206	16	230	29	217	42	288	18	33	22	73	685	2612
	73	151	156		30	801	59		116	759	175		67	115	109			
	Peak Hour Total:			380	Peak Hour Total:			890	Peak Hour Total:			1050	Peak Hour Total:			292		
			PHF:	0.8636364			PHF:	0.9673913			PHF:	0.91145833			PHF:	0.95052632	PHF:	0.95328467

A.5 First day Morning peak hour calculations

Table A. 5: First day 18/11/2015 Morning peak hour calculations

18/11 Morning	Saturday																	
	Intersection Eastbound				Intersection Northbound				Intersection Southbound				Intersection Westbound				Total Traffic	
Time	Right	Through	Left	Total	Right	Through	Left	Total	Right	Through	Left	Total	Right	Through	Left	Total		
7:00 - 7:15	1	1	2	4	1	55	2	58	2	40	3	45	3	2	4	9	116	
7:15 - 7:30	3	1	1	5	1	60	1	62	1	48	4	53	4	2	5	11	131	
7:30 - 7:45	8	6	2	16	0	88	2	90	2	105	4	112	5	1	10	16	234	
7:45 - 8:00	6	6	2	14	0	120	5	125	1	134	9	144	4	6	5	15	298	779
8:00 - 8:15	9	8	5	22	1	124	3	128	2	155	20	177	4	5	5	14	341	1004
8:15 - 8:30	4	7	7	18	4	99	10	113	1	116	5	122	4	8	6	18	271	1144
8:30 - 8:45	5	9	7	21	1	144	8	153	2	139	9	150	4	4	3	11	335	1245
8:45 - 9:00	8	9	8	25	3	117	4	124	1	209	11	221	5	12	12	29	399	1346
9:00 - 9:15	7	13	7	27	0	142	2	144	1	228	20	249	10	8	13	31	451	1456
9:15 - 9:30	6	9	8	23	2	145	12	159	1	193	11	205	7	12	8	27	414	1599
9:30 - 9:45	10	18	2	30	2	140	7	149	3	182	21	206	10	14	17	41	426	1690
9:45 - 10:00	6	12	7	25	3	176	8	187	2	167	24	193	8	14	9	31	436	1727
	29	52	24		7	603	29		7	770	76		35	48	47			
		Peak Hour Total		105		Peak Hour Total:		639		Peak Hour Total:		853		Peak Hour Total:		130		
			PHF:	0.875			PHF:	0.8542781			PHF:	0.8564257			PHF:	0.79268293	PHF:	0.95731707

A.6 First day Afternoon peak hour calculations

Table A. 6: First day Afternoon 18/11/2015 peak hour calculations

18/11 Afternoon	Saturday																	
	Intersection Eastbound				Intersection Northbound				Intersection Southbound				Intersection Westbound				Total Traffic	
Time	Right	Through	Left	Total	Right	Through	Left	Total	Right	Through	Left	Total	Right	Through	Left	Total		
7:00 - 7:15	11	12	5	28	3	153	6	162	4	231	21	256	10	18	22	50	496	
7:15 - 7:30	12	18	7	37	0	177	8	185	3	195	42	240	7	11	21	39	501	
7:30 - 7:45	7	22	8	37	2	175	9	186	3	202	32	237	8	25	29	62	522	
7:45 - 8:00	9	15	9	33	4	163	6	173	4	181	26	211	12	20	31	63	480	1999
8:00 - 8:15	8	17	12	37	3	167	7	177	5	193	28	226	15	19	28	62	502	2005
8:15 - 8:30	12	9	3	24	6	207	6	219	11	182	31	224	11	23	17	51	518	2022
8:30 - 8:45	14	23	9	46	4	160	9	173	5	196	24	225	5	21	30	56	500	2000
8:45 - 9:00	11	7	8	26	6	160	10	176	10	200	27	237	20	16	18	54	493	2013
9:00 - 9:15	13	14	6	33	7	163	13	183	12	186	24	222	15	15	28	58	495	2007
9:15 - 9:30	16	23	9	48	9	155	13	177	13	188	27	228	10	22	32	64	517	2006
9:30 - 9:45	14	11	4	29	6	195	5	206	10	143	28	181	11	23	27	61	477	1983
9:45 - 10:00	9	23	5	37	3	173	9	185	8	217	30	255	4	21	22	47	524	2014
	36	63	32		15	712	28		23	758	117		46	87	105			
Peak Hour Total:				131	Peak Hour Total:			755	Peak Hour Total:			898	Peak Hour Total:			238		
			PHF:	0.8851351			PHF:	0.8618721			PHF:	0.94725738			PHF:	0.94444444	PHF:	0.9583908

A.7 Second day Morning peak hour calculations

Table A. 7: Second day Morning 23/11/2015 peak hour calculations

23/11 Morning	Thursday																	
	Intersection Eastbound				Intersection Northbound				Intersection Southbound					Intersection Westbound			Total Traffic	
Time	Right	Through	Left	Total	Right	Through	Left	Total	Right	Through	Left	Total	Right	Through	Left	Total		
7:00 - 7:15	4	12	10	26	4	110	8	122	4	140	25	169	8	10	8	26	343	
7:15 - 7:30	5	20	17	42	5	129	9	143	6	156	29	191	12	14	10	36	412	
7:30 - 7:45	22	28	34	84	8	219	19	246	14	267	41	322	20	26	18	64	716	
7:45 - 8:00	24	34	32	90	2	202	19	223	33	237	57	327	43	50	20	113	753	2224
8:00 - 8:15	12	31	16	59	6	180	5	191	17	187	47	251	41	18	6	65	566	2447
8:15 - 8:30	8	20	17	45	2	155	5	152	14	144	25	183	7	16	15	38	428	2463
8:30 - 8:45	4	10	9	23	5	162	15	182	7	202	21	230	9	11	9	29	464	2211
8:45 - 9:00	4	18	22	44	3	154	3	160	6	187	20	213	7	21	4	32	449	1907
9:00 - 9:15	3	14	21	38	7	196	8	211	18	190	20	228	5	8	12	25	502	1843
9:15 - 9:30	4	17	20	41	6	145	7	158	8	174	24	206	6	21	7	34	439	1854
9:30 - 9:45	5	12	28	45	4	160	5	169	10	216	38	264	10	17	7	34	512	1902
9:45 - 10:00	10	10	24	44	5	170	7	182	11	182	20	213	15	14	10	39	478	1931
	63	113	99		21	730	52		70	847	174		116	108	54			
	Peak Hour Total:			275	Peak Hour Total:			803	Peak Hour Total:			1091	Peak Hour Total			273		
			PHF:	0.7638889			PHF:	0.8160569			PHF:	0.83409786			PHF:	0.61504425	PHF:	0.812417

A.8 Second day Afternoon peak hour calculations

Table A. 8: Second day Afternoon23/11/2015 peak hour calculations

23/11 Afternoon	Thursday																		
	Intersection Eastbound				Intersection Northbound				Intersection Southbound				Intersection Westbound					Total Traffic	
Time	Right	Through	Left	Total	Right	Through	Left	Total	Right	Through	Left	Total	Right	Through	Left	Total		
7:00 - 7:15	6	28	33	67	9	172	10	191	14	184	33	231	7	18	11	36	525	
7:15 - 7:30	14	22	27	63	4	181	9	194	19	184	40	243	10	20	6	36	536	
7:30 - 7:45	4	34	39	77	4	165	10	179	15	173	41	229	16	17	11	44	529	
7:45 - 8:00	10	28	43	81	10	162	9	181	19	182	39	240	14	27	9	50	552	2142
8:00 - 8:15	5	27	44	76	8	156	12	176	20	131	40	191	17	37	7	61	504	2121
8:15 - 8:30	11	38	42	91	4	153	5	162	21	189	46	256	16	20	15	51	560	2145
8:30 - 8:45	13	43	45	101	10	178	7	195	17	161	48	226	23	29	8	60	582	2198
8:45 - 9:00	18	21	47	86	6	177	10	193	28	172	29	229	17	26	5	49	557	2203
9:00 - 9:15	20	35	30	85	2	173	7	182	19	149	35	203	16	29	12	57	527	2226
9:15 - 9:30	13	33	52	98	7	203	12	222	30	158	28	216	10	25	7	42	578	2244
9:30 - 9:45	10	37	37	84	6	156	11	173	12	153	38	203	17	25	6	49	509	2171
9:45 - 10:00	14	31	25	70	8	206	13	227	21	184	23	228	18	27	9	54	579	2193
	64	132	174		25	731	36		94	640	140		66	109	33			
		Peak Hour Total:		370		Peak Hour Total:		792		Peak Hour Total:		874		Peak Hour Total:		208		
			PHF:	0.9158416			PHF:	0.8918919			PHF:	0.95414847			PHF:	0.86666667	PHF:	0.96391753

A.9 Third day Morning peak hour calculations

Table A. 9: Third day Morning 2/12 peak hour calculations

2/12 Morning																		
	Intersection Eastbound				Intersection Northbound				Intersection Southbound				Intersection Westbound				Total Traffic	
Time	Right	Through	Left	Total	Right	Through	Left	Total	Right	Through	Left	Total	Right	Through	Left	Total		
7:00 - 7:15	9	19	15	43	4	147	17	158	12	170	20	202	11	10	5	26	439	
7:15 - 7:30	12	20	19	51	5	159	18	182	13	190	22	225	19	11	8	38	496	
7:30 - 7:45	31	45	45	121	5	197	29	231	25	254	49	328	35	22	22	79	759	
7:45 - 8:00	23	48	33	104	3	203	7	213	30	232	52	314	42	37	17	96	727	2421
8:00 - 8:15	10	35	17	62	3	180	7	190	16	227	54	297	28	30	16	74	623	2605
8:15 - 8:30	16	13	11	40	5	184	7	196	14	167	34	215	13	15	6	34	485	2594
8:30 - 8:45	3	9	13	25	4	165	5	174	10	181	32	223	9	16	5	30	452	2287
8:45 - 9:00	4	12	14	30	2	164	15	181	12	169	24	205	11	13	7	31	447	2007
9:00 - 9:15	12	12	26	50	3	186	6	195	12	186	28	226	5	15	6	26	497	1881
9:15 - 9:30	9	13	19	41	3	193	2	198	21	170	30	221	9	11	6	26	486	1882
9:30 - 9:45	7	18	17	42	1	179	2	182	16	185	19	220	13	19	5	37	481	1911
9:45 - 10:00	10	21	23	54	2	178	16	196	20	209	22	251	12	17	10	39	540	2004
	75	148	114		16	739	61		84	903	177		174	100	63			
	Peak Hour Total:			338	Peak Hour Total:			816	Peak Hour Total:			1164	Peak Hour Total:			287		
			PHF:	0.6983471			PHF:	0.8831169			PHF:	0.88719512			PHF:	0.74739583	PHF:	0.85803689

B.10 Third day Afternoon peak hour calculations

Table A. 10: Third day Afternoon 2/12/2015 peak hour calculations

2/12 Afternoon																		
	Intersection Eastbound				Intersection Northbound				Intersection Southbound				Intersection Westbound				Total Traffic	
Time	Right	Through	Left	Total	Right	Through	Left	Total	Right	Through	Left	Total	Right	Through	Left	Total		
11:00 - 11:15	2	10	20	32	3	178	7	188	7	177	22	206	2	17	5	24	450	
11:15 - 11:30	7	21	23	51	2	191	6	199	9	175	21	205	8	17	6	31	485	
11:30 - 11:45	10	17	20	47	2	169	13	184	13	176	29	218	7	20	7	34	483	
11:45 - 12:00	9	18	14	41	8	145	2	155	11	160	26	197	9	26	12	47	440	1859
12:00 - 12:15	5	22	25	54	3	149	8	160	12	159	37	208	8	18	14	40	462	1871
12:15 - 12:30	12	27	21	60	4	193	7	204	17	168	42	227	14	25	13	52	543	1928
12:30 - 12:45	16	17	22	55	5	160	9	174	24	165	49	238	11	15	12	38	505	1950
12:45 - 13:00	11	32	21	64	6	162	13	181	25	185	42	252	8	26	13	47	544	2054
13:00 - 13:15	11	31	31	73	7	197	15	219	27	186	45	258	2	32	6	40	590	2182
13:15 - 13:30	20	38	34	92	6	170	12	188	19	176	50	245	16	25	11	52	577	2216
13:30 - 13:45	16	32	31	79	3	177	15	195	30	168	35	233	11	22	18	51	558	2269
13:45 - 14:00	17	41	36	94	5	156	16	177	29	169	42	240	10	33	20	63	574	2299
	64	142	132		21	700	58		105	699	172		39	112	55			
	Peak Hour Total:			338	Peak Hour Total:			779	Peak Hour Total:			976	Peak Hour Total:			206		
			PHF:	0.8989362			PHF:	0.8892694			PHF:	0.94573643			PHF:	0.81746032	PHF:	0.97415254

Appendix B: Signals Analysis Reports

Report 1: Existing conditions

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	112	148	83	73	122	132	65	786	22	194	898	89
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Util. Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.95	0.95	1.00	0.95	0.95
Frt			0.850		0.946			0.996			0.986	
Flt Protected		0.979			0.989		0.950			0.950		
Satd. Flow (prot)	0	1844	1601	0	1762	0	1789	3564	0	1789	3528	0
Flt Permitted		0.979			0.989		0.950			0.950		
Satd. Flow (perm)	0	1844	1601	0	1762	0	1789	3564	0	1789	3528	0
Satd. Flow (RTOR)			94		32			3			12	
Link Speed (k/h)		50			50			50			50	
Link Distance (m)		171.8			99.3			283.2			225.6	
Travel Time (s)		12.9			7.4			21.2			16.9	
Peak Hour Factor	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
Heavy Vehicles (%)	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Adj. Flow (vph)	127	168	94	83	139	150	74	893	25	220	1020	101
Lane Group Flow (vph)	0	295	94	0	372	0	74	918	0	220	1121	0
Lane Alignment	Left	Left	Right	Left	Left	Right	Left	Left	Right	Left	Left	Right
Crosswalk Width(m)		1.6			1.6			1.6			1.6	
Two way Left Turn Lane												
Headway Factor	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Turning Speed (k/h)	24		14	24		14	24		14	24		14
Turn Type	Split	NA	Perm	Split	NA		Prot	NA		Prot	NA	
Protected Phases	4	4		3	3		1	2		1	2	
Permitted Phases			4									
Minimum Split (s)	22.5	22.5	22.5	22.5	22.5		9.5	22.5		9.5	22.5	
Total Split (s)	22.5	22.5	22.5	22.5	22.5		15.4	35.7		15.4	35.7	
Total Split (%)	23.4%	23.4%	23.4%	23.4%	23.4%		16.0%	37.1%		16.0%	37.1%	
Maximum Green (s)	19.5	19.5	19.5	19.5	19.5		12.4	32.7		12.4	32.7	
Yellow Time (s)	2.0	2.0	2.0	2.0	2.0		2.0	2.0		2.0	2.0	
All-Red Time (s)	1.0	1.0	1.0	1.0	1.0		1.0	1.0		1.0	1.0	
Lost Time Adjust (s)		0.0	0.0		0.0		0.0	0.0		0.0	0.0	
Total Lost Time (s)		3.0	3.0		3.0		3.0	3.0		3.0	3.0	
Walk Time (s)	7.0	7.0	7.0	7.0	7.0		7.0	7.0		7.0	7.0	
Flash Dont Walk (s)	11.0	11.0	11.0	11.0	11.0		11.0	11.0		11.0	11.0	

Act Effct Green (s)		19.5	19.5		19.5		12.4	32.7		12.4	32.7
Actuated g/C Ratio		0.20	0.20		0.20		0.13	0.34		0.13	0.34
v/c Ratio		0.79	0.24		0.97		0.32	0.76		0.96	0.93
Control Delay		53.0	8.6		75.8		42.3	32.9		92.7	44.6
Total Delay		53.0	8.6		75.8		42.3	32.9		92.7	44.6
LOS		D	A		E		D	C		F	D
Approach Delay		42.3			75.8			33.6			52.5
Approach LOS		D			E			C			D
Stops (vph)		232	16		259		58	694		165	869

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	S SB
Fuel Used(l)		20	2		28		5	57		21	73
CO Emissions (g/hr)		367	42		513		95	1059		400	1364
NOx Emissions (g/hr)		71	8		99		18	204		77	263
VOC Emissions (g/hr)		85	10		118		22	244		92	315
Queue Length 50th (m)		52.4	0.0		63.8		12.7	78.8		41.2	103.5
Internal Link Dist (m)		147.8			75.3			259.2			201.6
Reduced v/c Ratio		0.79	0.24		0.97		0.32	0.76		0.96	0.93

Intersection Summary

Area Type: Other

Cycle Length: 96.1

Actuated Cycle Length: 96.1

Natural Cycle: 90

Control Type: Pretimed

Maximum v/c Ratio: 0.97

Intersection Signal Delay: 47.9 | Intersection LOS: D

Intersection Capacity Utilization 79.0% | ICU Level of Service D

Analysis Period (min) 15

Splits and Phases: 4:

Report 2: Optimizing signal timing

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	112	148	83	73	122	132	65	786	22	194	898	89
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Util. Factor	1.00	1.00	1.00	1.00	1.00	1.00	0.95	0.91	0.91	0.95	0.95	1.00
Frt			0.850		0.940			0.999	0.850			0.850
Flt Protected		0.973			0.988			0.995			0.988	
Satd. Flow (prot)	0	1833	1601	0	1749	0	0	3407	1457	0	3536	1601
Flt Permitted		0.973			0.988			0.836			0.652	
Satd. Flow (perm)	0	1833	1601	0	1749	0	0	2863	1457	0	2333	1601
Satd. Flow (RTOR)			109		41			1	109			109
Link Speed (k/h)		50			50			50			50	
Link Distance (m)		171.8			99.3			283.2			225.6	
Travel Time (s)		12.9			7.4			21.2			16.9	
Peak Hour Factor	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
Heavy Vehicles (%)	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Adj. Flow (vph)	127	102	94	83	102	150	74	682	25	220	682	101
Lane Group Flow (vph)	0	229	94	0	335	0	0	759	22	0	902	101
Lane Alignment	Left	Left	Right	Left	Left	Right	Left	Left	Right	Left	Left	Right
Crosswalk Width(m)		1.6			1.6			1.6			1.6	
Two way Left Turn Lane												
Headway Factor	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Turning Speed (k/h)	24		14	24		14	24		14	24		14
Protected Phases	4	4		3	3		1	2		1	2	
Minimum Split (s)	22.5	22.5		22.5	22.5		22.5	22.5		22.5	22.5	
Total Split (s)	22.5	22.5		22.5	22.5		22.5	22.5		22.5	22.5	
Total Split (%)	25.0%	25.0%		25.0%	25.0%		25.0%	25.0%		25.0%	25.0%	
Maximum Green (s)	19.5	19.5		19.5	19.5		19.5	19.5		19.5	19.5	
Yellow Time (s)	2.0	2.0		2.0	2.0		2.0	2.0		2.0	2.0	
All-Red Time (s)	1.0	1.0		1.0	1.0		1.0	1.0		1.0	1.0	
Total Lost Time (s)		3.0			3.0			3.0			3.0	
Walk Time (s)	7.0	7.0		7.0	7.0		7.0	7.0		7.0	7.0	
Flash Dont Walk (s)	11.0	11.0		11.0	11.0		11.0	11.0		11.0	11.0	
Pedestrian Calls (#/hr)	0	0		0	0		0	0		0	0	
Act Effct Green (s)		19.5	90.0		19.5			39.0	90.0		39.0	90.0
Actuated g/C Ratio		0.22	1.00		0.22			0.43	1.00		0.43	1.00
v/c Ratio		0.58	0.06		0.82			0.78	0.02		1.02	0.06
Control Delay		38.2	0.1		46.8			23.6	0.0		64.2	0.1
Queue Delay		0.0	0.0		0.0			0.0	0.0		0.0	0.0

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
LOS		D	A		D			C	A		E	A
Approach Delay		27.1			46.8			22.9			57.8	
Approach LOS		C			D			C			E	
Stops (vph)		177	0		232			448	0		592	0
Fuel Used(l)		13	1		18			40	1		69	2
CO Emissions (g/hr)		241	26		340			739	10		1280	36
NOx Emissions (g/hr)		47	5		66			143	2		247	7
VOC Emissions (g/hr)		56	6		78			170	2		295	8
Dilemma Vehicles (#)		0	0		0			0	0		0	0
Queue Length 50th (m)		35.7	0.0		48.9			47.5	0.0		76.7	0.0
Queue Length 95th (m)		56.9	0.0		87.5			61.3	0.0		109.2	0.0
Internal Link Dist (m)		147.8			75.3			259.2			201.6	
Turn Bay Length (m)												
Base Capacity (vph)		397	1601		411			869	1457		881	1601
Starvation Cap Reductn		0	0		0			0	0		0	0
Spillback Cap Reductn		0	0		0			0	0		0	0
Storage Cap Reductn		0	0		0			0	0		0	0
Reduced v/c Ratio		0.58	0.06		0.82			0.78	0.02		1.02	0.06

Intersection Summary

Area Type: Other

Cycle Length: 90

Actuated Cycle Length: 90

Natural Cycle: 90

Control Type: Pretimed

Maximum v/c Ratio: 1.02

Intersection Signal Delay: 41.1 Intersection LOS: D

Intersection Capacity Utilization 74.4% ICU Level of Service D

Analysis Period (min) 15

Splits and Phases: 4: